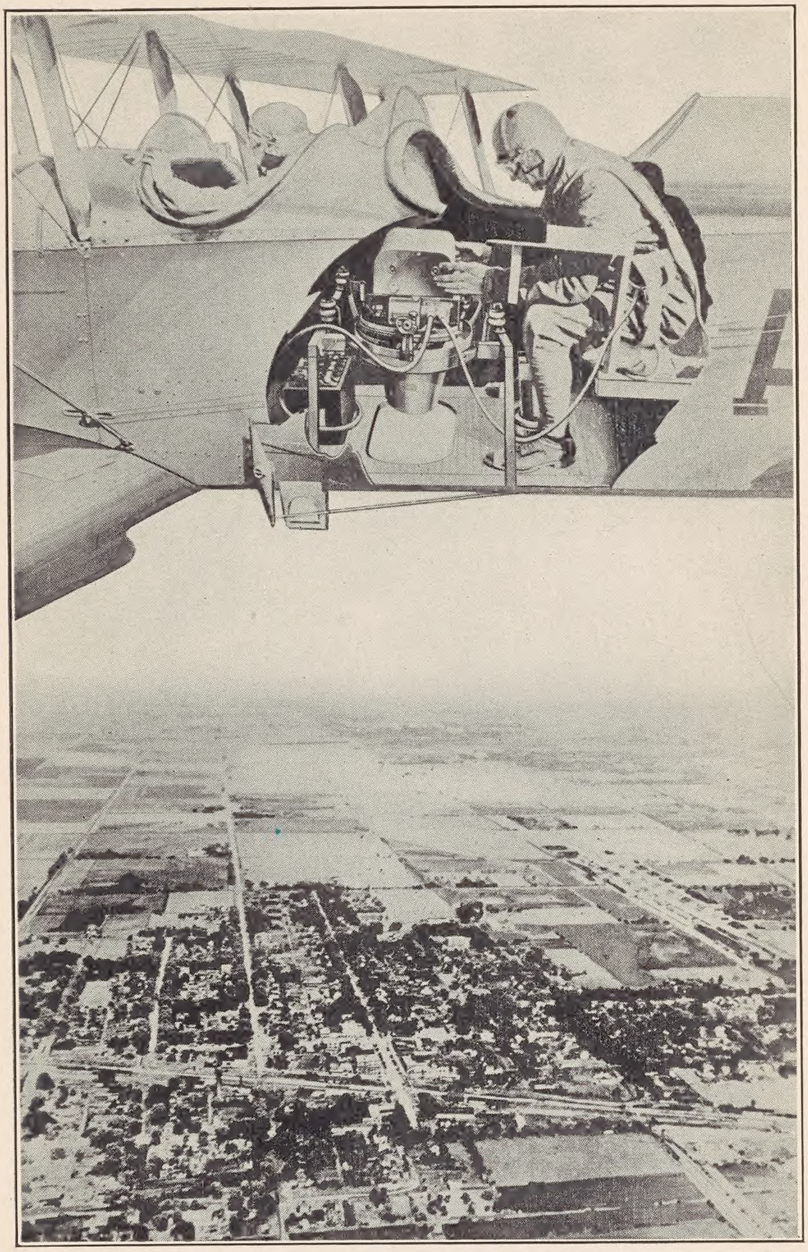

So very, very
true, and so
very, very
pretty.
Just as
pictured.

APPLIED AERIAL PHOTOGRAPHY



U. S. Army Air Corps

AERIAL PHOTOGRAPHIC MISSION IN OPERATION

Installation of K-3 camera outfit (camera, view finder, mount, battery, etc.) in a D. H. Army observation plane.

APPLIED AERIAL PHOTOGRAPHY

BY

ASHLEY C. McKINLEY

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WITH A CHAPTER ON

OBLIQUE AERIAL SURVEYS [CANADA]

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PREFACE

The purpose of this book is to make available under one cover a compact study of modern aerial photography. Published matter on this subject is today largely available only in scattered form in periodicals and pamphlets. Furthermore in view of the rapid development of aerial photography since the war most of this literature has become obsolete. An exception to this is the excellent work produced by the United States Army Air Corps, an invaluable source of material from which the author has obtained most of his data.

In the single decade since the world war, aerial photography has progressed from crude rule-of-thumb work to that of a science. Cameras and instruments are improved to a degree which at last makes accurate work possible. The success with which the U. S. Geological Survey, the Corps of Engineers of the U. S. Army, and the Surveys Bureau (Department of the Interior) of Canada have employed aerial photography substantially indicates its value as a surveying method of precision.

Engineers are gradually accepting aerial photography as a sound supplementary mapping method. It seems inevitable that the aerial survey must, in time, become indispensable for mapping. In mapping inaccessible territory the aerial survey has already assumed priority, as shown by the success of the Hamilton Rice Expedition in mapping hitherto inaccessible regions in tropical South America.

The author is deeply indebted to the United States Army Air Corps, not only as his primary source of information but as the school in which he received all of his training. He is also under obligations to Captain A. W. Stevens and Lieuts. Ployer P. Hill and Edward P. Gaines of the United States Army Air Corps, to Glenn Phelps, Edward R. Polley and F. O. Strowger. Particular thanks are due Miss M. E. Ferguson for her careful work on the manuscript. The book itself would never have appeared had it not been for my wife and Morton W. Royse, Ph.D., of Harvard

University, authority on aeronautics, to whom, in my absence with the Byrd Antarctic Expedition, was left all the labor of preparing the rough manuscript for publication.

Inasmuch as the Surveys Bureau of the Department of the Interior of Canada has done unique work in aerial surveying by the grid system the value of the present book is greatly enhanced by the addition of Chapter XXI by A. M. Narraway, now chief aerial surveys engineer of the Canadian Department.

A. C. McKinley.

June, 1929.

FOREWORD

When one opens the old family album and views the coldly severe pictures of grandma and grandpa, it is difficult to realize that these pictures marked the very beginning of practical photography. It is true that some of our ancestors, centuries and centuries ago, must have noted the tanning of the skin in the summer sun. Today it is possible, by use of a quartz lens and sufficient exposure, to make a negative upon the human body, and it is a comparatively simple matter to print through an ordinary celluloid negative, with the aid of ultraviolet light or sunlight, a positive picture upon one's own skin.

Even Adam in the Garden of Eden must have noticed the change in appearance of the skin of an apple, where a leaf or a twig hid its surface from direct sunlight. This was a true photographic process where a chemical change was effected by light itself, even though the exposure ran into a matter of days and weeks.

Less than eighty years ago, it was discovered that certain chemical salts were far more sensitive to light action. The principle of the lens was already known and it shortly became possible to make photographs much as we know them today. However, the time still ran into minutes and seconds of exposure. Development of more sensitive emulsions and the design of better lenses made high speed photography possible at the beginning of the present century. Some aerial photography had been accomplished with the aid of balloons and kites; therefore it was natural, with the advent of the airplane, that photography, previously a ground process, should receive extensive application in the airplane, The world war gave a great impetus to aerial photography, and aerial cameras were designed by the score. These cameras were made more with the intention of getting sharp, clear pictures of enemy territory than for the purposes of accurate topographic mapping.

In the years since the war much effort has been made to use the

aerial camera as an aid to the preparation of accurate maps or the making of good photographic mosaics. Much of this work naturally fell to the Air Services of the Army and Navy, and chief among the photographic officers who strove for better, and still better, results was Captain A. C. McKinley. Not only did he do outstanding work in the development of apparatus and the making of successful missions, but he endeavored to school others in the most practical methods of making successful aerial photographs. It was logical that he should be chosen by Commander Byrd's Expedition for the important pioneer work in aerial photography in the south polar regions.

Before Captain McKinley left on this mission he prepared the subject matter of this book, which is intended to give the would-be aerial photographer a practical working knowledge of modern aerial cameras, photographic emulsions, and photographic processes. While it is not possible to cover the story of photography entirely in one volume, it is believed that Captain McKinley has furnished the vital information that will put the average photographer on the right road to successful results.

It is to be remembered that at the time of publication of this volume Captain McKinley is still in the south polar regions coping with the inevitable difficulties and trials that any pioneer must meet while struggling under new and trying conditions.

Wright Field,
June, 1929.

A. W. Stevens,
Captain U. S. Army Air Corps.

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APPLIED AERIAL PHOTOGRAPHY

INTRODUCTION

Aerial Photography is the work of three types of craftsmen: the pilots and photographers, the laboratory personnel, and the draftsmen. The work of an aerial photographic organization, therefore, is divided into three departments. Although the duties of each of these departments are separate, it is absolutely essential that the closest possible cooperation exist between them. This can be accomplished effectively only when the entire personnel have a general understanding of each other's duties and problems and a general knowledge of the work of the topographer. Following the work of an aerial photographic section in operation, the subject of aerial photography naturally falls into three parts.

I. The first part covers the taking of aerial photographs. It includes the duties and problems of the pilot and photographer together with a study of navigation and photographic instruments.

II. The second part covers the work involved in finishing the photographs, the work of the laboratory personnel.

III. The third part covers the methods of using aerial photographs for mapping. Two general methods are used in applying aerial photographs to mapping, namely, making a map *with* the photographs and constructing a map *from* the photographs. The former method is covered in detail in this book since it comes directly under the work of an aerial photographic organization. The latter method, however, is treated in only a general way. Compiling maps from data obtained on aerial photographs is essentially the duty of a mapping agent or topographer. A sufficient amount of material on this subject, therefore, is included in order that the personnel of the three departments will have a fair understanding of the problems of the topographer when constructing a line map from aerial photographs. This knowledge

will lead to more efficient cooperation and will improve the general results. The topographer should also know something of the problems connected with the work of an aerial photographic organization, especially the work of the flying department.

Aerial photographic mapping is based on ground photography and surveying. Although many readers are doubtless familiar with one or both of these subjects it is deemed essential for the sake of clarity and convenience to touch upon them, thus making it possible for the average reader to continue through the book without the necessity of constantly referring to texts on these subjects. It is recommended, however, that the student of aerial photography, if he does not already possess a working knowledge of these sciences, make a fairly complete study of them.

Every photographic project or mission will have problems which concern that mission alone. It will be seldom that a regular routine can be followed from start to finish. There are certain operations, however, which will be performed regardless of the character of the mission in hand. These duties are performed in the following order:

1. The ground preparation by the flying crew. This will include:

   a. Locating the area to be mapped in relation to the point from which the flight is to start.

   b. Obtaining all necessary flying information in regard to that area, which will necessitate obtaining maps or making a reconnaissance flight or both.

   c. Choosing and installing the photographic and navigation instruments.

   d. A general study of the weather and light conditions to be expected over the area to be photographed.

2. Photographing the area.

3. Developing the aerial film. Due to its sensitive nature there will be a rapid deterioration of aerial film upon exposure to the air. This calls for development as soon as practicable after each flight.

4. The inspecting and numbering of negatives.

5. Making the prints. This is done by one of three methods, namely, contact printing, projection printing, and rectifying. The prints will be made by *contact* if the scale of the negatives is to be accepted as the scale of the prints. If a uniform scale is to be desired, all or part of the prints will be made by *projection*, that is, the prints will be made larger or smaller than the negative from which they are printed. If a uniform scale and corrections for tilt are desired, then a *rectifying camera* will be used. The resultant accuracy of these three methods increases in the order named. The speed of production, however, will decrease in the order named.

6. Making the index map.

7. Finally, preparing the map *from* or *with* the prints.

In a broad sense the methods of performing the operations 3, 4, and 6 are constant. Operations 1, 2, 5, and 7 will depend to a great extent upon the following factors: the accuracy required in the finished map, the use of the map, and the time and material allotted to the project. These factors, however, are very general. There will usually be other considerations which will have a direct bearing on the methods used, namely, the relief of the terrain, the size of the area to be mapped, the location of the area, both in respect to climate and distance from the home station, and the type of equipment.

There may be some mapping projects of sufficient size and distance from the home station to warrant the setting up of a small laboratory in the vicinity of the area to be mapped. This temporary laboratory will usually do only the work of finishing the negatives and preparing rough index maps therefrom. The remaining operations will almost always be performed at the home station. Due to the time saved in shipping film by Air Mail it will rarely be necessary to use a temporary laboratory when mapping areas included in the continental limits of the United States. When a large area, however, is to be mapped and it is so situated that it is beyond reach of fast transportation or located in a hot climate, it will always be advisable to set up a temporary laboratory.

A surprising amount of accurate work can be accomplished

daily by a small, competent, well-trained crew. The combination of quality and quantity, however, can be obtained only by a well-trained personnel. A trained laboratory crew of four men can finish from 200 to 400 aerial photographs during a ten-hour day. Using a single-lens vertical camera the pilot and photographer during a photographic day can fly and photograph from 100 to 250 square miles. Quality, rather than quantity, must always receive prime consideration. The quantity of work accomplished with speed is a very important factor, however, since the practical value, the *raison d'être* of aerial photography as a mapping method, rests upon the speed of action and the consequent wide range of operation.

Considering a map as a representation of details on the earth's surface, the aerial camera records these details in a manner impossible to obtain by any other method. In other words, every detail of the area covered by the camera is recorded. On the other hand, when a map is considered as an accurate location of points on the earth's surface, the work of the ground surveyor is more accurate. These citations are not intended to imply, on one hand, that the ground survey cannot record sufficient details; or, on the other hand, that distances cannot be measured on aerial photographs. They are intended rather to show that by combining the two methods the map produced will be the best possible representation of the earth's surface. The extent, therefore, to which either of these methods is used in surveying an area will depend upon whether the resultant map is to be used to study the features existing in the area or whether it is to be used to locate points accurately. The majority of mapping projects will necessitate combining to a greater or less degree these two methods.

Aerial photography has justified its existence as a surveying method by its two outstanding factors, namely, speed and recording of details. On the other hand, ground surveying is always needed to a greater or less extent on all photographic surveys except when the uncontrolled mosaic is used. The uncontrolled mosaic can only in a very broad sense be considered a map. In reality, it is only a composite picture of the earth's surface.

It may be noted that no one factor has retarded the advancement of both military and commercial aerial photography so much as the assertion of exaggerated claims. The most outstanding of these claims is that aerial photography has supplanted, or

will supplant, all ground surveying. No method for using aerial photographs has been devised or can be foreseen at this time which will make ground surveying obsolete.

As already stated, aerial photography when applied to mapping takes advantage of the data obtained by ground survey, but the new aerial method can be applied in so sweeping a manner that the *exclusive* use of ground mapping will in time become obsolete.

Part I

TAKING AERIAL PHOTOGRAPHS

CHAPTER I

THE DUTIES AND PROBLEMS OF THE PILOT AND THE PHOTOGRAPHER

The subjects treated in this chapter form the foundation of aerial photography. If the operations involved in the performance of the duties of the pilot and the photographer are not accomplished with precision and knowledge of the work, a project is destined from the start to be a failure. When flying and taking aerial photographs for a mapping mission the pilot and the photographer in reality become surveyors and each part of the equipment used becomes a surveying instrument. All operations, therefore, must be performed with the same accuracy as that demanded of a surveyor and his instruments on the ground.

The Personnel.—The personnel engaged in this work, that is, the pilot and the photographer, must be men who have had a thorough photographic training. The pilot must have as a foundation a natural flying ability and must be more than an average pilot. As will be seen, the pilot, even with this general technical background, must spend many hours practicing the methods to be used in flying a photographic mission.

The photographer need not have previous air experience although this qualification will be helpful, but he must undergo a thorough course in all branches of aerial photography.

Photographic Mapping Mission.—Each photographic mapping mission will be accomplished under different circumstances and conditions than all other mapping missions. The general routine, however, encountered on any mapping mission remains constant, and can therefore be described in a systematic order. Each problem connected with this routine will be treated separately in the sections of this chapter, and also a number of methods will be included for performing problems in different ways so as to meet new conditions as they arise. It will therefore be necessary to apply the methods to the regular routine as circumstances

require. Although different degrees of accuracy may be incorporated in the finished product, that is, in the mosaic or map, the photographs taken should not vary in accuracy. Each duty performed in the air must therefore be accomplished with all the precision that the personnel is capable of applying.

TYPES OF AERIAL PHOTOGRAPHS

There are two main types of aerial photographs, designated as **verticals** and **obliques.** There is also a combination of the two types, termed a **composite vertical.**

Verticals.—When an aerial photograph is taken with the optical axis of the camera vertical or nearly vertical it is termed a vertical photograph. In general, this term is applied regardless of the amount of tilt so long as the photograph is taken with the intention that the camera shall be vertical. In making mosaics, or in constructing line maps from them, the vertical photograph is employed almost exclusively. In reality, there is no true dividing line between these two types because practically all aerial photographs are inclined to a small degree.

Obliques.—The oblique photograph is one that is taken intentionally at an angle between the horizontal and the vertical. The oblique photograph is sometimes used for mapping, especially when the country is flat and a large area is to be covered. When an oblique is taken for mapping purposes the horizon is usually included in a straight line across the upper edge of the photograph.

Composite Verticals.—The composite vertical is really three pictures in one. The center picture is taken approximately in the vertical. The two wing pictures are taken with the optical axis inclined 35 deg. When these three pictures are printed, the center picture is printed as a vertical and the two wing pictures are projected through an angle to the vertical. The three pictures are then placed together as one composite picture.

ROUTINE OF A PHOTOGRAPHIC MISSION

Although every photographic mission will present some new and difficult problems, there will always be the prime factor to consider, that is, covering the area to be mapped with aerial

U. S. Army Air Corps

FIG. 1.—A VERTICAL PHOTOGRAPH

U. S. Army Air Corps

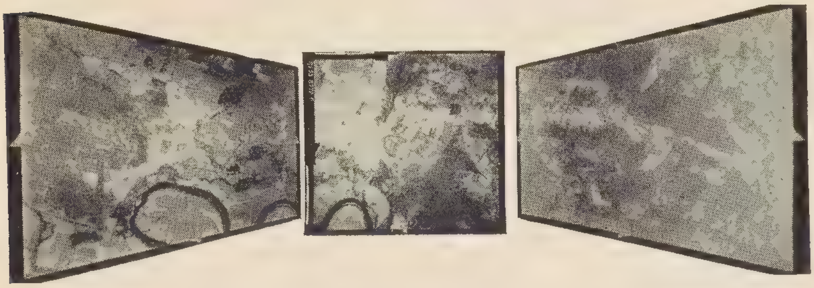
CANADIAN FALLS

U. S. Army Air Corps

AMERICAN FALLS

FIG. 2.—OBLIQUE VIEWS OF NIAGARA FALLS

photographs taken as near the vertical as possible. When the area is to be covered by vertical overlapping photographs there will always be some routine procedure that will be accomplished in the same manner as in preceding photographic missions. The area is to be covered, generally speaking, by flying the airplane methodically back and forth over parallel lines of flight until the whole area has been thus traversed. While the area is being flown in this manner, the photographer makes exposures in such a way as to obtain photographs with the desired overlap and taken as near the vertical as possible. The process is continued until the area to be mapped has been completely photographed.



U. S. Army Air Corps

FIG. 3.—EFFECT OF ONE EXPOSURE BY THE T-1 (TRI-LENS) CAMERA

The above procedure will usually be performed in the following order:

1. Before the flight is started, all preparations on the ground are completed, such as the loading of the camera and the installing of all photographic equipment, a careful routine inspection of equipment and instruments, the making of all necessary calculations and preparing a flight map. An essential element in these preparations is the plan of cooperation between the pilot and the photographer, calling for a thorough understanding by both pilot and photographer of all maneuvers to be made and all signals to be used.

2. When the airplane has reached the area to be photographed and has attained the altitude at which the mission is to be performed, the pilot then flies a sufficient distance to the rear of the starting point of the first strip so that on the return to that point the necessary amount of crab can be obtained at which the airplane must fly in order to pass directly over the ground course

of the first strip. The return to the starting point should be made in the same azimuth as that in which the first strip is to be flown. The photographer, during this interval of time before reaching the starting point, has obtained the time interval between exposures for that strip and has adjusted the camera in such a manner as to compensate for the angle which the airplane, after being crabbed to allow for the wind, is making with the ground course. The position of a single-lens camera should be such that the long diameter of the photograph forms the width of the strip and the line of flight passes through the center of the photograph and is parallel to its sides.

3. About ten seconds before the starting point is reached the pilot signals this fact to the photographer who then levels the camera and makes the first exposure as soon as the level bubble is centered. After the exposure has been made the photographer signals to the pilot. The number of the first exposure as shown by the reading on the camera is noted by the photographer, and the camera is then prepared for the next exposure. It is very important that the above duties be performed by the photographer in a systematic order immediately after each exposure. If this habit is not formed the result will be that some portion of the routine, at times, will be overlooked. During the time between the pilot's signal to the photographer and the giving of the exposure signal, little if any adjustment should be made in the controls of the airplane, especially during the last five seconds. (See paragraph on "Level Bubbles.")

4. The time interval which elapses between the photographer's signal, indicating to the pilot that the first exposure has been completed, and the next signal from the photographer is taken advantage of by the pilot to check the true course (air course), in order to make sure that it coincides with the ground course (the strip being flown). In case there has been a deviation from the ground course, the plane should be returned over the ground course and another adjustment made to compensate for drift. This change in the crab of the airplane should be closely followed by the photographer in order to readjust the position of the camera. The readjustment of the camera for any change in direction by the airplane should be made just before the next signal is given to the pilot. The photographer should also use this time to check the time interval obtained before the first exposure. If a view finder

is used, this check can be accomplished by catching an object appearing on the rear line of the view finder and noting the time required for that object to reach the front line of the view finder. This time should be the same as the time interval obtained before the first exposure.

5. Approximately fifteen seconds before the next exposure is to be made the photographer should again signal the pilot. The pilot then knows that he has ten seconds in which to make any adjustments necessary to steady and level the plane. The final adjustment in azimuth, if necessary, can also be made before the second signal. After ten seconds have elapsed the photographer sends the second signal to the pilot. This signal indicates to the pilot that only five seconds remain before the next exposure. During this interval no change in the position or speed of the airplane should be made by the pilot unless it is absolutely necessary.[1] At any instant, within the last three seconds before the time for the next exposure, when the photographer succeeds in centering the level bubble the exposure should be made.[2] When the second exposure has been completed the pilot is again notified and the same routine is followed as given for the time interval between the first and second exposures.

6. This procedure is continued until the end of the strip has been reached. At that point either the pilot or the photographer will give the other a signal that the strip has been finished.[3]

7. After reaching the end of the first strip the flight is continued in the same general direction for two or three minutes. A 180-deg. turn is then made, either to the right or left, as the case may be. This turn should be made so that it will be completed when the airplane is in the rear of and in line with the next strip to be flown. The interval of time, before reaching the starting point of the next strip to be flown, is used by the pilot and photographer to correct for the wind and to obtain the time interval for the second strip. If there is any wind the time interval and

[1] This method will reduce to a minimum the serious effect of centrifugal force on the level bubble.

[2] It is not always possible to center the level bubble at the exact second when the time interval elapses.

[3] When an accurate flight map is used the best results can be obtained by the pilot signaling the photographer.

the direction of crab will of course be different than when flying the first strip.

8. When the starting point of the second strip is reached a signal is given to the photographer and the same method of procedure is started and continued as given for the first strip. The remaining strips of the area are flown and photographed in the same manner as the first and second strips. This is continued until the entire area to be mapped has been covered by overlapping photographs.

In the operations involved in covering a designated area with overlapping photographs it can therefore be seen that the pilot, photographer, camera and airplane must, figuratively speaking, become one machine. This machine should have perfect coordination among its parts. A movement by one part of this imaginary machine must be followed by an accurate adjustment of all other parts of that machine. The accuracy of the final result of a photo mission will be proportionate to the approach made to perfect coordination of the parts of this machine. This point has been especially emphasized because the value of aerial photography as a mapping instrument is distinctly dependent on this factor, namely, on the coordination between the pilot and photographer and their working tools.

GROUND PREPARATION

All photographic mapping missions, before the flight is started, are preceded by certain preparations on the ground. Each mission will usually demand special ground preparations that cannot be foreseen and given in a general outline, but there are certain routine preparations that must always be accomplished for all photographic mapping missions before flight is begun. These routine preparations are usually carried out as follows:

1. The pilot and photographer together study the existing map or maps of the area to be photographed.[1] Plans should also be made as to the order in which the flight is to be carried out. The photographer must know the manner in which the pilot intends

[1] If no existing maps of the area to be photographed are available a reconnaissance flight must be made. The method of carrying out a reconnaissance flight is explained in the paragraph under that heading, p. 44.

to cover the area. The following factors should be known by the photographer before the flight is started:

a. The strip that will be flown first and the direction in which the flight is to be made.
b. The time and method of the approach before reaching the starting point of each strip. This must be known by the photographer so that he will be able to determine the amount of time available in order to adjust for crab and obtain the time interval between exposures.
c. The signals for the routine flying and photographing must be decided upon. (See the paragraph under "Signals.") A pre-determined signal should also be agreed upon for use in cases where it is necessary for either the pilot or the photographer to attract the other's attention. It may be that the photographer will need some additional time to obtain the interval between exposures or to adjust for crab before starting a strip. If the procedure to be followed in events of this kind is not thoroughly understood by both parties concerned great confusion in the air will result. Some means of verbal communication, of course, will make an understanding in the air much easier.

2. The following information must be available before making the flight:[1]

a. The number of exposures necessary to cover the area.
b. The number of photographs necessary to complete each strip.
c. The approximate time interval between exposures should be known, as this information will serve as a check on the time interval obtained in the air.
d. The altitude at which the flight is to be made should be determined.
e. The overlap, both lateral and successive, should be decided upon.
f. The amount of film necessary to complete the project should also be known.

[1] See paragraph under "Computations," p. 19.

g. The focal length of the lens to be used will be determined by the desired scale of the photograph and the altitude to be flown.

3. A careful and systematic inspection of all equipment and instruments (see "Instruments") should be made. This inspection should also include the airplane. It is advisable to "service" and ground-test the airplane the day or night before the expected photographic flight. In cool weather the camera can be loaded and installed (see "Camera Installation") in the airplane the day or night before the flight.

4. A flight map should be prepared in the following manner:

Preparation of Flight Map.—The area to be photographed is plotted on a map that is suitable for flying. A suitable flight map may be classed as one on which objects on the ground are easily identified on the map. After the flight map has been plotted with the area to be photographed the proposed lines of flight are next plotted on the map. These are used by the pilot as guides when flying back and forth across the area during photographic operations. The lines of flight should be so spaced that the strips of photographs, made as each line is followed in flight, will overlap the adjoining strips the desired amount on the sides. The following example will illustrate the method for determining the distance between the lines of flight.

Let it be supposed that a K–3 camera, equipped with a 12-in. focal length lens, is to be used on a photographic mission to be flown at an altitude of 10,000 ft. From computation made according to the formula contained in the paragraph under "Computations" it will be found that in width a strip of photographs made at that altitude with the aforementioned camera will cover 7,500 ft. on the ground. This figure is reduced to the map distance. The first line of flight is so plotted on the map that one-half the width of the photographs will extend over the boundary of the area. The practice is to cover an area so that sufficient margin will be shown around it in the completed mosaic. The starting point of the first strip having been plotted on the map with reference to the considerations mentioned, the starting points of the subsequent lines of flight are calculated and plotted as follows: If it is desired that the side of each strip of photographs overlap

the side of the adjoining strip to an extent, for instance, of 50 per cent, then this figure is subtracted from 100 per cent and the remaining 50 per cent is multiplied by 7,500 ft. The result will

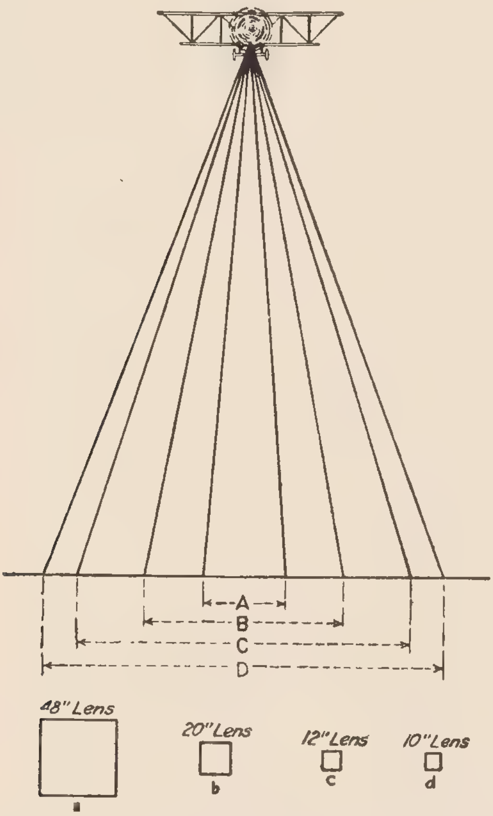


Fig. 4.—Comparison of Area Covered with Size of Images Recorded by Lenses of Different Focal Length

be the distance between the first and the second strip and between each of the subsequent strips measured from the center thereof.

Computations.—The following computations and formulas will assist in solving most of the necessary mathematical problems connected with the ground preparation for a photographic mission.

The Ground Area Covered by a Photograph of a Given Size at a Given Altitude and with a Given Focal Length:

Let s = the scale, expressed as a representative fraction.
h = the height or altitude.
f = the focal length of the lens.
W = the width of the ground covered by the photograph.
w = the width of the plate.
L = the length of the ground covered by the photograph.
l = the length of the plate.
v = the speed of the airplane in feet per second.
t = the time interval in seconds between exposures.

Then
$$s = f/h.$$
$$W = h/f \times w.$$
$$L = h/f \times l.$$
$$t = \frac{\frac{2}{3}W}{v} \text{ for } 33\tfrac{1}{3} \text{ per cent overlap or}$$
$$t = \frac{\frac{1}{2}W}{v} \text{ for 50 per cent overlap.}$$
$$h = f/s.$$

The proportion is
$$l : L :: f : h \qquad \text{or} \qquad l/L = f/h.$$

Example.

Altitude: 3,000 ft.
Focal length of lens: 12 in.
Size of plate or film: 18 by 24 cm., take the available surface to be 7 by 9 in.

To find the dimensions of the area covered on the ground.

Solution.—The proportion is:
$l : L :: f : h.$

Substituting values,

$9 : L = 12 : 36{,}000$ (3,000 ft.).
$12\ L = 324{,}000$ in.
$L = 27{,}000$ in.

or, 2,250 ft. = ground distance covered by *long* side of plate.

AREAS COVERED AT DIFFERENT ALTITUDES, AND SCALES OF THE PHOTOGRAPH; FOR THE VARIOUS LENSES

(7×9 in. net area covered)

10-in. Lens				12-in. Lens				20-in. Lens			
Altitude, Feet	Ground Covered, in Feet		Scale	Altitude, Feet	Ground Covered, in Feet		Scale	Altitude, Feet	Ground Covered, in Feet		Scale
	Length	Width			Length	Width			Length	Width	
3,000	2,100	2,700	1–3600	3,000	1,750	2,250	1–3000	3,000	1,050	1,350	1–800
4,000	2,800	3,600	1–4800	4,000	2,333	3,000	1–4000	4,000	1,400	1,800	1–2400
5,000	3,500	4,500	1–6000	5,000	2,916	3,750	1–5000	5,000	1,750	2,250	1–3000
6,000	4,200	5,400	1–7200	6,000	3,500	4,500	1–6000	6,000	2,100	2,700	1–3600
7,000	4,900	6,300	1–8400	7,000	4,083	5,250	1–7000	7,000	2,450	3,150	1–4200
8,000	5,600	7,200	1–9600	8,000	4,666	6,000	1–8000	8,000	2,800	3,600	1–4800
9,000	6,300	8,100	1–10800	9,000	5,250	6,750	1–9000	9,000	3,150	4,050	1–5400
10,000	7,000	9,000	1–12000	10,000	5,833	7,500	1–10000	10,000	3,500	4,500	1–6000
11,000	7,700	9,900	1–13200	11,000	6,416	8,250	1–11000	11,000	3,850	4,950	1–6600
12,000	8,400	10,800	1–14400	12,000	7,000	9,000	1–12000	12,000	4,200	5,400	1–7200
13,000	9,100	11,700	1–15600	13,000	7,583	9,750	1–13000	13,000	4,550	5,850	1–7800
14,000	9,800	12,600	1–16800	14,000	8,166	10,500	1–14000	14,000	4,900	6,300	1–8400
15,000	10,500	13,500	1–18000	15,000	8,750	11,250	1–15000	15,000	5,250	6,750	1–9000
16,000	11,200	14,400	1–19200	16,000	9,333	12,000	1–16000	16,000	5,600	7,200	1–9600
17,000	11,900	15,300	1–20400	17,000	9,916	12,750	1–17000	17,000	5,950	7,650	1–10200
18,000	12,600	16,200	1–21600	18,000	10,500	13,500	1–18000	18,000	6,300	8,100	1–10800

Again substituting,

$$7 : W :: 12 : 36{,}000$$
$$12\ L = 252{,}000 \text{ in.}$$
$$L = 21{,}000 \text{ in.}$$

or, 1,750 ft. = ground distance covered by *short* side of plate.

The ground area covered is 1,750 by 2,250 ft.

Determining Exposure Interval.—If under the conditions cited in the example given above it is desired to make a strip of photographs covering an area, or to take a number of photographs for the making of a composite picture or mosaic, the individual photographs must overlap. If it is decided that the overlap (or margin of safety) should be one-third of the length and width of each photograph, the interval of exposure is determined as follows: The photographs are taken with the width of the plate or film parallel to the line of flight and therefore an exposure must be made every time two-thirds of the width of the ground space is flown. Two-thirds of 1,750 ft. equals 1,167 ft. Each time a distance of 1,167 ft. is added to the distance already flown an exposure must be made.

The air speed of the airplane should be calculated in feet per second as an exposure must be made each 1,167 ft. flown. If the air speed of the airplane is 90 miles an hour, or 132 ft. a second, then an exposure must be made every 8 seconds, which is the interval between exposures.[1]

To Take Pictures at a Certain Scale.—If the scale is represented by s, then

$$s = l/L = f/h.$$

If it is desired to make photographs on the scale of 1 : 10,000 with a lens of 12-in. focal length, the altitude (in feet) at which it is necessary to fly is determined as follows:

Since $$s = f/h.$$

Then $$h = \frac{f}{s} = \frac{12}{\frac{1 \times 12}{10{,}000}} = 10{,}000 \text{ ft.}$$

[1] Wind velocity and direction, with relation to lines of flight, can be determined with the view finder. (See under "View Finder.")

U. S. Army Air Corps

FIG. 5.—HIGHEST-ALTITUDE PHOTOGRAPH

An exposure made at an unprecedented altitude of over 7 miles (39,150 ft.), by Captains A. W. Stevens and St. Clair Streett. Details are to be noted in spite of the fact that the altitude was double that at which practical mapping can be carried out.

From computations made by the Bureau of Standards from the barograph records, the elevation on this flight was found to be 37,854 ft. The four highest negatives include the above, and were very carefully measured by Lieutenant Bruce C. Hill and assistants of the Corps of Engineers, U. S. Army. Lieutenant Hill put a surveying party into the field and made six traverses of the particular area included in the four highest photographs. Exact determination of the focal length of the lens was made. The focal length proved to be 9.347 ins. From measurements of the images on the negatives, determinations of true altitude were made. These calculations were rather intricate, requiring as much as 12 hours for a single set of calculations. Four calculations were made from each negative making sixteen calculations altogether. The whole process of determining the altitude by this method took over a month. Results checked closely, with an error estimated to be not over 50 ft. The above photograph proved to be the highest picture and the elevation, so determined, was 39,150 ft. It may be noted that in the United States the National Advisory Committee for Aeronautics had recently compiled a new set of tables for the measurement of true altitude. The Bureau of Standards determined that the elevation computed from the N. A. C. A. tables was 39,606 ft. This figure checks reasonably closely with the altitude as determined from the camera. It is still believed that the camera method is by far the most accurate.

Determining Altitude from Which a Photograph was Made.—If it is required to find the height from which a photograph has been taken, the following data must be known:

1. Focal length of lens used.
2. Horizontal distance between two points on the ground that can be identified on the photograph.

Example.—Suppose that the distance between two points on the photograph is measured and found to be 2.5 in. and that the horizontal distance on the ground is 1,500 ft., or 18,000 in., then the scale expressed as a representative fraction, is

$$\frac{2.5}{1{,}500 \times 12} = \frac{1}{7{,}200}.$$

If the focal length of the lens used in making the photograph is 12 in., or one foot, then

$$\text{Altitude} = \frac{\text{focal length}}{\text{scale}} = \frac{1}{\frac{1}{7{,}200}} = 7{,}200 \text{ ft.}$$

It will be noted from the foregoing computations that when using a lens of 12-in. focal length many of the computations can be quickly made mentally.

Computing the Scale on Vertical Aerial Photographs.—The scale of an aerial photograph depends on the altitude at which the photograph was made and the focal length of the lens used in making the photograph.

Let f = the focal length of the lens in inches, and h = the altitude in inches and s the scale. Then $\frac{f}{h} = s$. Thus, if a photograph is made at 5,000 ft. with a 12-in. lens,

$$\frac{12 \text{ in.}}{5{,}000 \text{ ft.}} = \text{the scale.}$$

The 5,000 ft. must then be reduced to inches.

$$\frac{12}{60{,}000} \text{ or } \frac{1}{5{,}000} = \text{the scale.}$$

If the photograph is taken at 5,000 ft. with a lens having a 20-in. focal length,

$$\frac{20 \text{ in.}}{5{,}000 \text{ ft.}} = \frac{20 \text{ in.}}{60{,}000 \text{ in.}} = \frac{1}{3{,}000} = \text{the scale.}$$

T-1 Camera.—For making approximate calculations it is convenient to know that at any elevation chosen for a photographic flight, when the T–1 Camera is used, the width of the terrain photographed will be three times the elevation, and its length per full roll of film will be one-third of the elevation multiplied by 190.

U. S. Army Air Corps

Fig. 6.—Constructed Works, Such as Reservoir, Dam, Roads, Buildings, Shown in High-altitude Photograph

A high-altitude photograph taken over Wright Field, Dayton, Ohio, from an altitude of over 6 miles (32,450 ft.), by Captain A. W. Stevens and Lieutenant J. E. Doolittle of the U. S. Army Air Corps. This photograph illustrates the precision with which details can be reproduced at enormous heights. The clouds appearing in the exposure are some 25,000 ft. below the plane.

For example, at an elevation of 15,000 ft. with the photographs overlapping 60 per cent, terrain approximately 9 miles wide and 190 miles long could be mapped on one roll of film 6 in. wide and 380 ft. long.

The Season and Time of the Day.—When planning to map a large area, the prevailing weather conditions of the area become

an important consideration even when the mission is given a choice of season. Although the records of the United States Weather Bureau are too general to indicate percentages of days suitable for aerial photography, nevertheless the best season and

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FIG. 7.—EQUIPMENT USED ON HIGH-ALTITUDE FLIGHTS

The two bottles on the right are liquid oxygen containers together with their vaporizers. On the left is seen the camera, which was electrically heated. Electrically heated gloves were used and the wires may be seen running down the sleeve of the suit to the gloves. On this particular flight goggles were used, with air holes drilled just in front of the pupils of the eyes. On subsequent flights, electrically heated goggles have been used which have done away with frosting at temperatures as low as 76 degrees below zero Fahr.—the temperature usually encountered at the highest altitude. This temperature is about the same, winter or summer.

probably the month when the best general weather conditions are to be expected can be determined from this source. The meteorological bureaus of the state in which the territory to be photographed is located can also be relied upon for general information. Records of the weather for Dayton, Ohio, and vicinity, were kept

by the U. S. Army Air Corps, especially to determine how many days of a year could be counted on for taking aerial photographs suitable for map making. This record, extending over a period of 1,187 days, shows that aerial photographs for mapping could be taken all day during 277 days; during 81 days, photographs could be taken for five hours; during 74 days, they could be taken

U. S. Army Air Corps

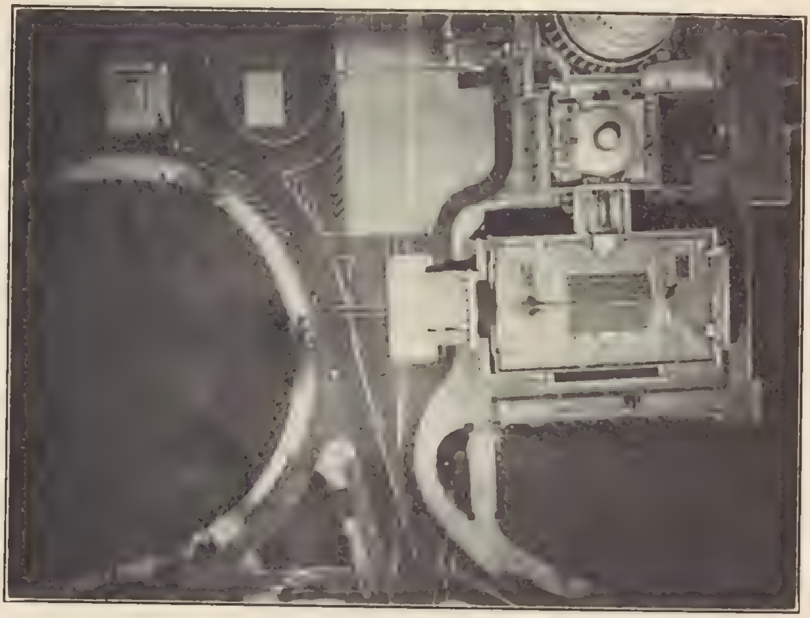
Fig. 8.—Photograph Made at Ten o'clock at Night by Means of Apparatus Recently Devised by the Materiel Division of the U. S. Army Air Corps. Elevation 1500 Ft.

In this picture, with a reading glass, people can be seen standing on the sidewalks beside the automobiles. On the filling station near the railroad intersection (lower center of view) may be seen ten incandescent lamps, each one a pinpoint of light.

for three hours; and for 40 days, one hour. Out of 1,187 days, the total number of days when aerial photographs could be taken was 472 days. Although this record was kept for only one locality, it is probably typical of most of the Mississippi Valley. There are parts of the United States where the number of photographic days would show a great increase over this number, for example,

in the Southwest. On the other hand, especially along the sea coasts, the number of good photographic days would be less than this number.

Recent improvements in aerial film and lenses have increased the length of the photographic day. It is now possible to work in any part of the United States during any season of the year. In the extreme northern part of the United States it is possible to



U. S. Army Air Corps

FIG. 9.—COMBINED PROCESS OF NIGHT PHOTOGRAPHY AND RAPID DEVELOPING IN AIRPLANE

Made at 10:30 P.M. over the Capitol, March 3, 1929. The picture was developed in the airplane itself, and was dry ten minutes after the flashlight had been fired. Two minutes later the dry picture was dropped in a tube to officials of the American Telephone & Telegraph Co., who immediately transmitted it by wire to San Francisco, Chicago, New Orleans, New York, and other points for press publication.

work throughout the winter for about three hours around noon. With lenses working at *f*.4.5 and using hypersensitized film, aerial photography is possible when the sun is only 15 deg. high. This figure should be used as a limit rather than as the usual time to start taking pictures. When a small area is to be mapped and the appearance of the photograph is a consideration, as would be the case in making a mosaic of a city, the middle of the day should be

selected as the time to take the pictures because the shadows will not be so long at that time as early in the morning and late in the afternoon.

FLYING THE STRIP

The Take-off and Landing.—Both the take-off and landing should be accomplished as smoothly as possible in order not to disturb the adjustment of the instruments used in connection with the photographic work. If a choice is possible, that portion of the field which is most free of mud or dust should be used. A take-off on muddy or dusty ground may cause dirt to adhere to the surface of the lens. The nose of the camera should, therefore, be protected until the plane has reached an altitude where all danger of this kind has passed. The top of the camera should be pushed forward so that the nose will point toward the tail of the plane. As an extra precaution it is advisable to tie a clean cloth over the nose of the camera especially if the nose of the camera, after it has been tipped back as far as it will go, is not within the plane.

Climbing to the Mapping Altitude.—If the landing field is in the vicinity of the area to be photographed it is excellent practice to climb over the area and study it while ascending. Some airplanes climb steadily and easily on a day when the air is smooth. Therefore, after properly setting the stabilizer the time required to reach the mapping altitude can be used advantageously to observe the ground which is to be mapped and check the essential points along the lines of flight and to compare them with the flight map. The climbing performance of airplanes will vary with the type, each airplane having different air speeds at which it will climb most efficiently at different altitudes. This climbing efficiency will vary with airplanes of the same type, depending upon the trim of the craft and the load carried. A test will be necessary, therefore, to determine for each type of photographic airplane the most efficient air speed for climbing. When this test is made the weight of the photographer and equipment should be included. It is also important that this weight be distributed in its normal positions.

The special photographic airplane used in the Army, for example, climbs most efficiently at an air speed of 80 miles per hour at the start of the flight, and approximately 1 mile per hour

should be deducted for each thousand feet climbed. When climbing at 10,000 ft., therefore, this plane will climb most efficiently at an air speed of 70 miles per hour.

FLYING STRAIGHT, LEVEL AND AT A CONSTANT ALTITUDE OVER PHOTOGRAPHIC STRIPS

Flying over the parallel strips while performing a photographic mission is essentially a matter of navigation. In the ordinary process of navigating an airplane to the desired destination, accuracy is required only at the point of arrival, and considerable latitude is allowed in the method and manner of approach. Much greater accuracy is demanded when flying over the strips of a photographic mission. Not only must the pilot leave one point and arrive at the other with precision, but he must consistently fly over a straight line between those points.

The impression is quite common that it should be rather easy to fly vertically over a ground course between two predetermined points. This fallacy is held not alone by the layman, but is surprisingly prevalent among skillful pilots who have not flown photographic missions at high altitudes.

The Operations and Errors Involved.—When flying an aerial photographic strip, after having located the strip to be flown and having started over it in the correct azimuth, the pilot has three separate operations to perform. These operations are: flying an airplane over a straight line on the ground between the starting and finishing point of the strip to be flown; keeping a constant altitude between these points; and holding the airplane level throughout the flight, especially for the few seconds just before the photographer makes the exposures. The three maneuvers have a direct effect on each other. If there is a distinct change in altitude there may also be a change in the wind either in direction or velocity or in both. This will cause the airplane to drift from the ground course if the same angle of crab has been maintained as that used at the altitude from which the change was made. The pilot, upon finding that he is drifting from his course and has deviated from the altitude to be maintained, will, of course, attempt to correct these deviations. In doing so he will first use the rudder to return the craft over the course. By so doing, he will have caused the airplane to deviate from level flight. If the airplane has

skidded and the wings are held approximately level the instruments will cease to give a true reading. (See "Level Bubble.") To return to the proper altitude the pilot will necessarily use the elevators or change the r.p.m. of the motor. When the former is done the nose of the craft will be raised or lowered; in the latter case the instruments will again give an incorrect reading caused by the change in the acceleration. When the airplane is not flying level, that is, when either wing is low, the airplane will be following a curved path rather than a straight one. The three flying operations, therefore, although each operation is separate, have a direct bearing on each other.

Each of the aforementioned operations contains a photographic error if not performed with accuracy. If the airplane is not held over a straight line connecting the starting and finishing points of the strip, the camera will not be centered over that line at the point or points where the deviation occurs. As parallel strips are to be flown with a predetermined overlap of the photographs between the strips, these deviations from the line of flight will cause a change to be made in the overlap. And if these deviations are large there may even be spaces between strips not covered by the photographs.

When a constant altitude is not maintained the photographs will be taken either at a greater or a less distance from the ground than intended, resulting, therefore, in every photograph, taken at an altitude other than the intended altitude, having an incorrect scale.[1]

When the airplane is not flown level, or is changing direction or speed at the time the photographer is preparing for or making an exposure the photograph taken under these circumstances will not be a vertical photograph but rather will be an oblique. If this photograph, taken with the camera tilted from the true vertical is exposed over an area of irregular relief, the result of the tilt will produce an even greater error. (See "Tilt and Relief.")

Of the three errors involved, the tilted airplane and deviation of direction are the most serious. Of these two, the effect of tilt will give the most trouble to the map compiler. As mentioned before, this error will be increased when combined with relief.

[1] The effect of changes in altitude on the scale of the photographs is discussed in the paragraph on "Computations," see p. 19.

Although changes in scale of the photographs, caused by flying at different altitudes, are not difficult to correct when the photograph is taken with the camera vertical, nevertheless, when combined with relief or tilt or both, the photograph cannot be enlarged without increasing the magnitude of those errors.

The three flying operations and the three correlated errors, therefore, are so intermingled that the only solution is to combine the three operations and treat them as one maneuver. This feat, of course, is much easier said than done.

A general plan for flying a photographic strip unfortunately cannot be laid down as the conditions governing each photographic mission will usually vary. At times these conditions will vary with each strip flown in the same mission. The following factors, however, will govern the method to be used when flying a mission:

1. The features that can be easily identified along the course that can be used by the pilot as a guide.
2. The accuracy of the flight map to be used on the flight.
3. The ease with which the existing ground features can be read on the flight map.
4. The smoothness of the air during the flight.
5. The length of the strips to be flown.
6. The navigating instruments used and their dependability.
7. The stability and "visibility" of the airplane to be used.

The two factors which have the greatest bearing on the method of flying over the strips are the flight map and the available navigating instruments.

The Horizon.—The pilot must have a reasonably accurate appreciation of the vertical in order to be able to fly a straight ground course between two predetermined points. To be able to fly directly over objects on the ground while flying a straight course, the pilot must fly so that a point vertically below the airplane and on the ground course travels along a line which intersects the objects on the ground course. No difficulties should be encountered so long as the pilot knows both the vertical and the direction of motion. As long as the airplane is flying straight and at a steady speed the pilot's sense of the vertical should remain practically normal. But if the airplane is subjected to horizontal accelerations then his estimation of the vertical will be erroneous and all instruments designed to record the vertical which depend

upon gravity, with the reading indicated by them, will be subject to the same errors.[1]

All normal flying can be said to be based on the pilot's realization of the relation of the airplane to the horizon. The average pilot is not conscious of the extent to which he relies upon the horizon as a gage by which to maintain the airplane in level flight. When flying a photographic strip, the inexperienced photographic pilot may fix his attention on some object along the ground course and neglect to look at the horizon. This may cause the approach to that object to be made in a curve or series of curves rather than in a straight line. Often the ground horizon is invisible from the altitude at which a photographic mission is flown, but in this case it is usually replaced by the haze horizon. The errors in this haze horizon are much less than the accidental tilt. Therefore it can be used to determine the approximate vertical because under such conditions it is the most reliable means available.

Sensitiveness of the Controls.—It has been found that a more sensitive touch of control is provided by the rudder and aileron than the pilot can feel and that the inherent longitudinal and lateral stability of the plane will limit the extent of rolling and pitching more effectively than the pilot can, within limits, so that he had better leave the control of one degree or less to the plane, with the controls free rather than to over-control by attempted correction.

Selection of Points along the Ground Course.—Much better results can be obtained if it is possible, as the airplane flies over the course, to continue selecting objects along the course which are some distance ahead instead of below the airplane. At the start of the strip it is especially important that the pilot be able to see two points along the course to be flown. When two points can be seen the pilot can align the airplane by these two points and adjust his course until the track of the airplane coincides with a line joining the two points.

The Length of the Strips.—A factor of importance is the size

[1] Rolling and pitching are always present, even when the air is supposedly calm, in the form of periodic, slow, accelerations caused by the action of the restoring forces of the airplane's inherent stability. The oscillations are of the order of magnitude of from one-half to one and one-half degrees within the period of about 20 seconds depending upon the inherent stability of the airplane.

and shape of the area to be photographed in one unit. Of more importance, is the length of the strips to be flown. The area, in fact, can be made indefinitely large, subject to the provision that the length of the strips have a definite limit. If the strips flown are too short an inadmissible amount of time is wasted in dead flying during the maneuvers at the end and start of each strip. If the strips are too long the difficulties in following a straight course will be increased to the extent that it will be practically impossible for the pilot to maintain the overlap between parallel strips. When strips only ten miles in length are flown the dead flying at the turns will be from 20 to 50 per cent of the useful miles flown. In most cases it will be found possible for an experienced photographic pilot to fly, with the required accuracy, strips from 25 to 35 miles in length. Passable strips have been flown as long as 60 miles, but with the present available methods it is recommended that strips not over 35 miles in length be flown except over country exceptionally well marked and mapped, as, for example, where parallel roads follow the section lines over the entire area to be mapped. Such ideal conditions are seldom encountered. If the area to be mapped is square the lines of flight should be governed by the number of objects that can be identified along the courses, especially at the ends of the strips. If the features of a square area are uniform throughout, the only factors which will give any basis in favor of a particular direction of flights are the northerly turning error of the compass, which makes it preferable to fly in an east-west direction, and the prevailing wind over that area. If good visibility can be obtained from the plane to be used, when flying without necessary crab and when there are no other factors to be considered, then it is probably best to map out the flight with and into the prevailing wind.

Maintaining a Constant Altitude.—Experience indicates that pilots skilled in photographic flying can maintain an elevation without varying more than 100 ft. for distances as great as 35 miles. When the weather is satisfactory for aerial photography the atmospheric pressure remains fairly constant at a given elevation over comparatively flat country. Maintaining a constant altitude is much more important than flying merely at a given general altitude. For this reason, it is advisable to use some form of a sensitive statiscope in connection with the altimeter. If, for some reason, the photographs must be taken at a given scale a

correction for temperature should be made when reading the altimeter, this being the most serious error connected with altimeters. (See Altimeters under "Instruments.") A constant altitude is more easily secured by using the throttle. Having adjusted the vertical stabilizer so that the airplane maintains its altitude over a period of time, the pilot, by referring to his instruments, can see whether or not the plane is gaining or losing altitude slightly. If gaining or losing, small corrections should not be attempted with the stabilizer; rather the speed of the motor should be increased or decreased a few revolutions per minute. It has been found that, unless there is a decided change in altitude or unless the air is very rough, it is best to correct slight fluctuations in altitude by using the throttle rather than the elevators.

PHOTOGRAPHING THE STRIP

The photographer has four routine duties to perform while the pilot is flying over the photographic strip: namely, adjusting and readjusting the camera to compensate for the crab of the airplane in relation to the ground course; obtaining and maintaining the correct time interval between exposures so that the photographs will be taken with the predetermined overlap; holding with precision the camera pointing vertically down; and making each exposure and preparing for the next. The accurate performance of these duties is greatly simplified when the pilot on his part is successful in performing his numerous duties with precision. This is not always possible even when the pilot is expert in photographic piloting. The photographer can not control the medium from which the photograph is taken. He must, therefore, make all corrections within his power for any deviation from the ideal of the airplane, *the ideal being a level platform moving ahead at a constant speed in a straight line over the exact area to be photographed.*

The photographer has four instruments with which to perform these operations. These instruments are the view finder, the mount, the level bubble or bubbles on the camera, and the camera itself. Each of these instruments is described in detail in the chapter on Cameras and Accessories under Part I. If the view finder is not available then a drift indicator must be used. The description and operation of the drift indicator will be found in the chapter on Navigation Instruments under Part I. This

instrument can be used in the same manner as the view finder though the latter is to be preferred.

Adjusting the Camera for Crab.—On approaching the starting point of each strip the pilot will crab the airplane in order to make allowances for the wind if the wind is coming from any direction other than straight up or down the course to be flown. As the airplane's heading is changed to make this allowance for the wind, so must the photographer change the position of the camera. This change of the camera must be made regardless of the heading of the airplane. The straight line between the starting point and finishing point should be made to pass through the center of the long side of the magazine. The sides of the magazine should be parallel with that line. The following method is used to find the position for the camera.

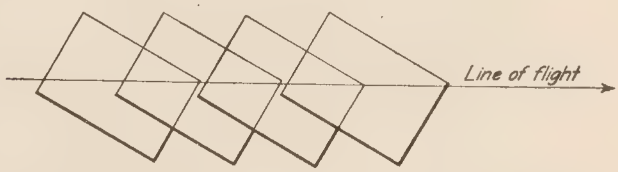


FIG. 10.—EFFECT OF NOT ADJUSTING THE CAMERA TO COMPENSATE FOR CRAB

The view finder is first brought to an approximate vertical position by centering the level bubble on that instrument. The view finder is then turned in such a position that images of objects on the ground will travel parallel to the longitudinal lines (a half inch apart) ruled on the ground glass. When this has been accomplished the camera should then be oriented with relation to the view finder. In this position, so long as the airplane keeps the same heading as when the reading was taken, the edges of all photographs taken with the camera will be parallel to the photographic strip being flown. If the airplane is accurately over that strip, a line between the starting and finishing point will pass through the center of the photograph taken at that time. Continued check should be made with the view finder, while the strip is being flown, to ascertain if the airplane has maintained the same heading as when the first reading was taken. When this is not the case a correction is made in the position of the camera.

The Time Interval.—The correct time interval between exposures is also obtained by using the view finder in the following manner.

With the level bubble on the view finder centered and the instrument adjusted for the crab of the airplane, that is, when images of objects on the ground are traveling parallel to lines ruled on the ground-glass, the photographer should start a stop watch as any one of these images reaches the rear traverse line ruled on the ground-glass. The lapse of time required for the image to reach the other traverse line, also ruled on the ground-glass, will be the time interval between exposures to be used on that strip. The time interval should be rechecked throughout the flight over that strip. This check can be made by locating an image on or near the rear traverse line each time an exposure is made. The time for the next exposure has arrived when this image reaches the same position relative to the front traverse line as was its position relative to the rear traverse line. During this operation the camera is of course maintained at the vertical. About five seconds before the exposure is made the photographer should begin to level the camera and have it as near the vertical as possible at the time of exposure. This operation is accomplished by centering the level bubble, or bubbles, on the camera. To center a level bubble, the photographer must look directly down on that bubble so he will not obtain a distorted impression of the relation of the bubble to the center of its container. At any time that the photographer, during the last few seconds preceding the elapse of the time interval, is successful in centering the level bubble with precision, the exposure should be made.

Exposure.—After the level bubble on the camera has been centered the exposure is made by either pressing or pushing the trigger to the shutter. This operation should be accomplished in somewhat the same manner as firing a gun, that is, the trigger should be pulled or pushed slowly rather than jerked. After the exposure has been made the photographer prepares for the next exposure. (See discussions of "Cameras.")

The preparation for the next exposure should always follow immediately after the exposure has been made. If this procedure is not carefully followed the photographer will frequently overlook it until the time for the next exposure and after the camera has been leveled. This will necessitate a hurried preparation resulting

in throwing the camera off level and by the time that it can be re-leveled the plane will have traveled a sufficient distance to reduce the overlap of that exposure appreciably.

Signals.—A system of signal lights should be included in a photographic airplane even though some means of verbal communication is available. It is absolutely essential that the pilot and photographer be able to communicate with each other. Verbal communication, if successful, will prove the most satisfactory. When light signals are used, the lamps should be so placed that when lighted they will be seen immediately. The habit of passing notes back and forth between the pilot and photographer is very unsatisfactory and inefficient. When visual signals are used, they must be well understood by both parties concerned before leaving the ground. This is a matter often neglected and results in poor work, if not in a complete failure of the mission. The common practice of rocking the plane by the pilot to indicate when the start and finish of a strip is reached is not satisfactory as the readings of all instruments are thus disturbed just when they are needed. A flash of the photographer's light will be a much better means of notifying the photographer when to start and stop taking pictures. The photographer will know approximately when to expect the flash, therefore it need never be missed. The photographer should give the pilot two signals before each exposure and one when the exposure has been completed. There should be thirty seconds between the first and second signal and usually about five seconds between the second signal and the signal indicating that the exposure has been made. When the first signal is given, the pilot levels and steadies the plane if necessary. During the interval between the second signal and the exposure signal the pilot should not make any change in direction or speed of the plane and, unless it is absolutely necessary, he should not attempt to make any adjustments whatever of the controls during the period between the second and third lights.

If there has been no change in azimuth or speed during this interval, the level bubble on the camera will give a true or almost true reading. (See paragraphs on "Level Bubble.") It is of the utmost importance, therefore, that at this time a steady stable condition be maintained.

Overlap.—The usual procedure is to secure an overlap between successive exposures of about 60 per cent, and for the adjoining

strips an overlap on each other of about 50 per cent. The former is usually termed "endlap" and the latter "sidelap." The net effective area of each exposure will thus be 20/100 of the area of one exposure. This corresponds to 2,900 square miles at a scale of 8 ft. to 1 in., which will mean that each object on the ground will be photographed five times. In actual practice the required amount of overlap is not always realized because of the difficulty experienced in flying an airplane in perfectly straight lines and maintaining perfect parallelism between successive strips. The importance of securing sufficient overlap will become apparent from the following considerations:

1. The central portion of a vertical photograph shows objects in practically vertical projection. Elevated objects become displaced near the edges and in the case of a slightly tilted camera the edges are more subject to distortion than the center of the photograph. The center of the photograph, therefore, is the only area that can be safely used in constructing a mosaic or a map.

2. In order that a large number of photographs may be assembled into a consistent map to a uniform scale and reasonably free from distortion, certain geometric principles must govern. To make this possible the center point of any one exposure must appear in the exposures on either side of it.

3. When viewing aerial photographs stereoscopically ample overlap is a prime requisite. In order that any portion of an aerial photograph may be studied in the stereoscope the overlap must not be less than 50 per cent between any two successive exposures.

4. Sufficient overlap also makes it possible to eliminate the occasional defective exposures caused by tilting of the camera, by small clouds, cloud shadows, or other imperfections.

5. The sidelap is primarily needed in order to insure continuity between adjacent strips and to afford a safety margin for any irregularities in flight direction and alignment. When flying at high altitudes these irregularities will occur at times.

The Altitude.—The altitude at which a photographic mission is to be flown will depend upon the desired scale of the photographs and upon the focal length of the lens used. It is generally recommended that mapping should not be done under 9,000 ft. There are two reasons for this recommendation. The first, and most important, is that the air under 9,000 ft. is subject to disturbances

caused by the temperature and nature of the terrain. The second reason is that at low altitudes too many photographs will be required to cover the area. When circumstances permit, 15,000 ft. is probably the best mapping altitude. It is much more efficient to fly at a high altitude and, if a large scale is desired, to enlarge the photographs to the desired scale.

A photograph that is taken with a good lens can usually be enlarged four times. In some cases enlargements as high as eight diameters have been made.

Length of the Exposure.—It is customary when taking aerial photographs for mapping purposes to give an exposure of 1/50 of a second, this being approximately the longest exposure that can be given with safety, that is, without blurring. (See descriptions of "Mounts.") There is an altitude limitation for each focal length at which this exposure can be given. The following figures may be used as a guide:

When the ground speed of the airplane is 60 miles per hour, or over, the exposure of 1/50 of a second must be decreased (generally to 1/100 of a second) as follows:

If a lens of 10-in. focal length is used, the exposure must be decreased at altitudes under 3,500 ft.

If a lens of 12-in. focal length is used, the exposure must be decreased at altitudes under 4,000 ft.

If a lens of 20-in. focal length is used, the exposure must be decreased at altitudes under 6,000 ft.

From the foregoing it follows that the exposure should be decreased when the focal length is increased or the altitude decreased. The reason for this conclusion applies equally to both cases: that is, the larger the projected image the faster it will travel across the plate, and when the focal length is increased, or altitude decreased, objects projected on the plate will be proportionately larger. Although it has been stated that 1/50 of a second is ordinarily used in mapping this length of exposure, nevertheless this interval is merely a limitation by which blur may be stopped or reduced. When a photographer continues to use this exposure, regardless of the circumstances, he is performing his duties purely mechanically and not taking advantage of all available factors which control exposure. With the working speed of the present available film and lens it will often be possible for the photographer to reduce this exposure limit. In doing so several errors, or prob-

able errors, are likewise reduced, namely, blur caused either by vibration or speed over the ground, movement of the camera, and most important, when mapping, the distortions caused by the shutter.

General Exposure Data.—The speed of the lens, film, and stop are considered constant in the following approximate comparisons:

Problem 1: Time of the Year.—In this comparison the months are considered in three groups as follows.

Group 1: April, May, June, July and August.
Group 2: February, March, September and October.
Group 3: January, November and December.

If the time and kind of day are constant and Group 1 is considered as one unit of exposure, then consider Group 2 as one and a half units, and Group 3 as two units. In other words, if 1/50 of a second exposure gives a normal negative in Group 3, then 1/100 of a second would give a normal negative in Group 1.

Problem 2: Time of the Day.

Group 1: the hours of 10, 11 and 12 a.m. and 1 and 2 p.m.
Group 2: the hours of 9 a.m. and 3 p.m.
Group 3: the hours of 7 and 8 a.m. and 4 and 5 p.m.

With all other factors constant, and with Group 1 given the value of one unit, Group 2, is given one and a half units, and Group 3, two units. In this comparison the value of the units can be applied the same as in Comparison 1.

Problem 3: The Kind of Day.—Considering that the units have the same value as in Comparisons 1 and 2, then:

Intense sunlight will be one unit.
Bright sunlight will be one and a half units.
Diffused sunlight will be two units.
A dull day will be two and a half units.
A very dull day will be three units.

The foregoing comparisons are intended only to be used as a foundation on which to build, with experience, a knowledge of the exposure to be given under all circumstances. As a reminder the following factors must also be considered:

1. The speed of the plate or film.
2. The speed of the lens.
3. The stop used (if any).

4. The altitude at which the mission is flown.
5. The focal length of the lens used.
6. The filter factor (if a filter is used).[1]
7. The latitude and longitude of the area over which the photograph is taken.[2]
8. The ground speed and vibration to be overcome.

Level Bubbles as Horizontal Indicators.—At the present time the level bubble is the device generally used for indicating to the photographer when the camera is pointing vertically down. Tests made by the U. S. Army Air Corps have proven that the level bubble will indicate the horizontal with sufficient accuracy to be used for aerial photographic mapping. These tests were made by taking twelve photographs over specially prepared targets on flat ground where measurements and calculations were made to obtain comparisons between data of inclination (amount and direction) as shown by the level bubble and by the calculations. It was found that whenever the calculations showed an amount less than 1 deg. of inclination, the level bubble indicated both direction and amount of inclination quite accurately. About 85 per cent of the photographs tested were inclined less than 1 deg. About 95 per cent were inclined less than 2 deg. and the bubbles indicated the amount and direction of their inclination sufficiently well to supply the vertical point with the accuracy necessary for the radial line method. On only 5 per cent of the photographs did the level bubble falsely indicate the amount and direction of inclination so that the data obtained from the level bubble were of no direct value.

It is desirable to have level bubble data register on all vertical photographs taken for mapping use. The arrangement of the bubble is either such that an auxiliary lens will project its image on the negative or vials are placed in the focal plane of the camera to form shadow images. The former method has been applied to a single-lens camera, the latter to the center chamber of the tri-lens camera.

The level bubbles will register inclination and the true direction of the inclination with sufficient precision only when the plane

[1] See chapter on "Air Haze."

[2] The latitude and longitude of the area where the photograph is taken have an effect on two exposure factors, namely, the season of the year and the time of the day when the sunlight is the brightest.

is flying at a constant speed and on a straight course. When the airplane is subject to accelerations caused by either an increased or a decreased speed in the line of flight, or by flying in a curve rather than a straight line, the level bubble will show an incorrect reading in inclination and direction. This error in reading under these circumstances is caused by centrifugal force. It is, therefore, not the fact that the airplane is tilted which is serious but that the airplane is changing direction. The photographer cannot ascertain when this force is acting upon the level bubble, since the same force affects the photographer causing him to lose his true appreciation of the vertical. A test with a carpenter's level will show the effect of centrifugal force on the level bubble of the camera. If the carpenter's level is placed on a flat surface inclined, for example, 3 deg. from the horizontal, for all practical purposes the level will register 3 deg. and show the correct direction of tilt. If the level bubble is placed on a flat horizontal surface it will register zero, but if the flat horizontal surface is swung in a curve the bubble will cease to register zero. If the surface in the same position is moved forward the bubble will again be off center, but if the forward motion is continued at the same speed the bubble will return to the center. With the bubble centered and the flat horizontal surface moving forward at a constant speed, any acceleration or deceleration will again cause the bubble to move off center. If the surface tilted at 3 deg. were moved forward at a constant speed the bubble would still show a correct reading. But the plane, unfortunately, will not fly in this position, since practically as soon as one of the wings drops, and remains lowered, the airplane will start in a curved flight and will regain a straight level flight only when the wings are brought back to the horizontal.

It is for the foregoing reasons, as already mentioned, that the pilot should be given two signals instead of one before each exposure is made. The first signal enables him to check his direction and level the ship if necessary. After the second signal the pilot should watch only the horizon and not the instruments within the plane or objects along the ground course, since the horizon, true or haze, is the most reliable information of the horizontal.

The Composite Photograph (with Tri-Lens Camera).—In order to provide more suitable angles of intersection the tri-lens camera (on some photographic missions) is intentionally crabbed in regard to the strip on the ground to be photographed. The

most useful angle of crab is about 15 deg. The photographs of two adjacent strips should be skewed in opposite directions.

RECONNAISSANCE FLIGHT

When the area to be photographed has not been previously mapped the difficulties encountered by the pilot and photographer will be greatly increased, especially in the case of the pilot. In this event, the entire mission will necessarily be carried out by navigation. The length of the strips must be determined by the number of exposures made. To make it possible to carry out a mapping project under these circumstances a reconnaissance flight must be made over the area to be mapped. Before the reconnaissance flight is started, several factors should be determined:

1. The exact distance and direction of the nearest corner of the area to be mapped from some point located on the flying field.

2. The size and shape of the area to be mapped must be determined so as to be able to decide the boundary on which to make the reconnaissance strip.

3. The boundary of the area from which the flights or strips will start should be decided and the length and azimuth of that boundary from the corner of the area to the nearest flying field must be determined.

4. The length of the strip and the number of exposures necessary to complete each strip and boundary are then determined, also the number of strips necessary to complete the area.

5. Two easily identified points on the flying field or in the near vicinity should be selected. These two selected points must be on an imaginary line drawn from the flying field to the near corner of the area to be mapped.

6. When the data from 1 to 5 inclusive have been determined, the pilot and photographer should plan the reconnoitering flight, that is, they should decide upon the routine to be followed.

Equipment.—The following equipment and material should be taken on the reconnaissance flight: a mapping camera, a view finder or drift indicator, instruments to be used in connection with navigation, and a sheet of paper with a straight line drawn across it five inches from one edge. This line is used to represent the border of the area from which the flights or strips will start.

Lines should be also drawn on the paper perpendicular to the starting line, these lines representing the lines of flight or strips to be followed.

Order of Reconnaissance Flight.—When the foregoing ground preparations have been completed, the reconnaissance flight should be carried out approximately in the following manner and order:

1. At the altitude from which the reconnaissance strips are to be taken, fly over two selected points on the flying field in the direction of the near corner of the area to be mapped. During this flight the pilot should note the drift necessary to arrive at this point in a straight flight. The photographer should observe the ground speed and determine the time interval necessary to arrive at the near corner of the area to be mapped from the selected point on the flying field.

2. The pilot then flies back of the two direction points and again passes over them in the direction of the near corner of the area. As the starting point on the flying field is reached, the photographer observes the time or, even better, starts a stop-watch. When the interval of time necessary to reach the near corner of the area to be mapped has elapsed, the pilot is given a predetermined signal by the photographer. Then the pilot should observe the area surrounding this corner and select an easily identified point on the ground at or near the corner of the area. This point will serve as the starting point for the reconnaissance strip.

3. The pilot then flies to the rear of the selected point at the corner of the area and approaches this point flying a ground course that will represent the starting boundary of the area to be mapped. As the selected point is reached, the pilot gives the photographer a predetermined signal to start photographing. The photographer, having adjusted the camera for drift and having determined the time interval and the exposure during the approach to the point, upon the signal from the pilot starts taking photographs. When the required number of exposures has been made to complete the photographing of the starting boundary, the photographer then signals the pilot that the end of the starting boundary has been reached. During the flight along the boundary, the pilot must give most of his attention to following the correct ground course. This necessarily must be accomplished by navigation. During the photographing of the boundary the plane should be flown at

a constant speed and as near the same altitude as possible in order not to change materially the time interval between exposures, this being the only means available to determine when the end of the strip has been reached. The altitude at which the reconnaissance flight is flown is immaterial, just so the scale of the photographs is sufficiently large to enable one to identify objects on the ground in the photograph.

4. After the starting boundary of the area has been photographed a flight is made over the entire area. This is accomplished by flying back and forth over the ground course which will be flown when the area is actually being photographed. During this flight the photographer marks on the flight lines of the aforementioned paper, prepared for that purpose, all points that will help the pilot to identify the ground course to be flown. The points on the ground should be noted on the paper by conventional signs or by some other satisfactory system so that the pilot will be able to identify the ground by referring to the paper. The interval of time necessary to cover each strip during the reconnaissance flight need only be taken on the first two strips. These two time intervals may be used for the remainder of the strips flown during the reconnaissance flight.

Preparing the Flight Map.—After returning to the field the roll of film taken during the reconnaissance trip is developed and printed. These prints are then assembled in the form of a strip mosaic and are pasted on the boundary line that was drawn on the paper on which the photographer marked identifying objects during the reconnaissance flight. This paper will then serve as a reasonably good flight map. The value of this improvised flight map can be increased by taking photographs of the border parallel to the starting border of the area to be mapped. If this additional photographic strip is made it is also assembled in the form of a strip mosaic and pasted on the opposite side of the flight map. If still further improvement of the flight map is necessary, obliques can be taken of the strips as the boundaries are being flown and the verticals are being made. The amount of time spent and material used in constructing the flight map must be determined by the information that will be required from it in order to photograph the area successfully. No more time, of course, should be spent in this connection than is necessary for the pilot to be able to identify the area to be flown from the flight map.

The use of control points has not been considered thus far. If they are available or are to be located for the construction of the finished product then they should also be used in connection with the flying for and construction of the flight map. Control points will be especially useful in this connection when they are located at or near the corners of the area to be mapped, since in this position they will serve as a means of locating the area from the flying field and of locating the start and finish of the boundary or boundaries to be photographed for the flight map.

Marking and Identifying Control Points.—It will sometimes be necessary, especially in sparsely settled country, to mark the control points. Marking should be limited to a minimum as it takes time and some points are rather difficult to reach. Whenever possible, natural objects, such as cross-roads, road forks, or intersections of fence lines, should be chosen for control. If traverses are run to provide control a wealth of natural objects will be found along roads, railroads, or other courses taken by traverses. If the control is to be established by triangulation, there will not be readily available so many natural objects suitable for photographic targets, but usually some common object near a station can be tied to it.

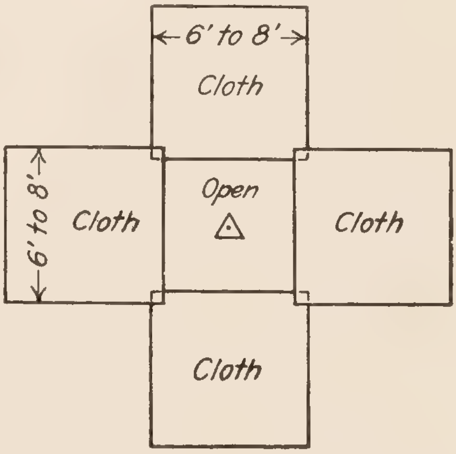


Fig. 11.—Form of Panels for Control Points

Whenever artificial targets are required they can be constructed of strips of white cloth in the form of a hollow cross. This cross should be well fastened with short pegs or heavy stones to prevent its blowing away. The crosses are usually made of panels about 6 ft. square, which is sufficiently large providing the scale of the proposed photograph is not under 1:20,000. For smaller scale photographs the panel should be approximately 8 ft. square. White lime can also be used in place of the cloth. If the pictures

are to be taken in the winter, when there is snow on the ground or snow in patches, the cross should be of some dark color.

Summary.—The general summing up of the material contained in this chapter leads to the following conclusions:

1. The amount of navigation necessary to fly a photographic strip is inversely proportional to the number of easily identified objects along the course to be flown and the readability of those objects on the flight map used.

2. The most important factor involved in flying a straight ground course is a level airplane. When the pilot is unsuccessful in this operation all other factors involved in the flight may be in error.

3. When the starting point of a strip is reached the pilot must be flying in the same azimuth as that strip and to accomplish this maneuver with precision the airplane must be aligned with two points on the strip. When only one point is used a plane may pass directly over the starting point, flying a straight course, and still be at an angle of any number of degrees with a straight line between the starting and finishing points of the strip.

4. When flying in an airplane the truest indicator of the horizontal is the true horizon. Next in accuracy is the haze horizon.

5. On almost every day suitable for aerial photographic mapping either the true or haze horizon can be seen.

6. Within the limits of the pilot's ability to fly a straight course, the photographic strips should be flown over the longest dimension of the area to be mapped.

7. The predetermined end and side overlap should be maintained within very close limits as it is within this overlap that the map or mosaic compiler obtains much of the necessary information.

8. Every maneuver involved during a photographic mission should be performed with precision, there being very few "abouts" connected with this work.

9. The most effective means of communication available between pilot and photographer should be adopted.

10. It is much more efficient to make too many exposures than to make too few.

11. If for some unforeseen reason part of the area to be photographed has been missed, due to camera failure, it is the best procedure to re-fly and re-photograph that portion of the area

during the same flight rather than attempt to complete it on another day when an entirely different condition may exist.

12. As seen in the paragraph on aerial haze it is usually best to use film not less sensitive than hypersensitized panchromatic. The choice of filters should be carefully made to suit the day on which the photographing is done.

As a final conclusion, although the pilot and photographer are confronted with numerous difficult problems, if they are well trained and furnished with reliable instruments photographs of sufficient accuracy covering a large area can be obtained.

CHAPTER II

AIR HAZE

ANY substance that tends to diminish the transparency of the atmosphere is a source of haze. Haze may be caused by water vapor, irregular temperature distribution, dust, smoke, or even dry air. Haze may be uniform to high altitude or stratified near the ground or at a great height; it varies in color, depending upon its source and the size of the particles that it contains. These suspended particles scatter light, creating a veiling glare between the camera and the ground. The various rays of which light is composed possess a distinct photographic (chemical) effect. The blue, violet, and ultra-violet rays are called "chemically active rays." The red and yellow rays are known as "chemically clear rays." The chemically clear rays have a shorter wave length, and the chemically active rays have a longer wave length. In consequence of the shortness of the waves of the blue, they are much more dispersed in the ether in space than the other rays. For this reason, for instance, the sky is blue. The shorter and more chemically active rays are scattered by the suspended particles composing haze, where it has very little effect upon the longer and more chemically clear rays. The human eye and light sensitive material are entirely different as to color sensitivity, the eye being more sensitive to the longer rays of the spectrum. Therefore, often when atmospheric conditions are visually clear, haze conditions will exist that have a serious effect photographically.

Aerial mapping is affected by haze more than by any other condition affecting photography, the camera being always several hundred feet, usually several thousand feet, from the objects being taken. High altitude photography is affected by haze to the extent that it is often difficult to distinguish details in the photograph, unless some means are used to overcome the effects of haze. At times the haze will be so dense that the ground will be hard

to see at low altitudes and almost invisible from 10,000 ft. This condition can exist when there are no cloud formations. When haze is extremely dense it is practically impossible to photograph through it, as under these conditions the radiation reflected from the haze is greater than that reflected from the ground.

Our visible perception of objects at a distance depends on contrast, that is, on the difference in the light reflected. If the contrast of a subject is dimmed it will be very difficult to distinguish the detail, and since the object of aerial photography is to be able to read or interpret details in the subject photographed, the effect of haze, if not eliminated, will produce a very serious loss in efficiency.

It can be seen that haze and its effects are of primary importance in the taking of aerial photographs. The effect of haze can be controlled by the color of the light by which the photograph is taken. This is done by using the longer light waves of the spectrum, the longer waves being less affected by haze. The length of the wave used can be determined by the sensitive material used, the character of the exposure, the developer, the time of development, and by the use of screens or filters.

Filters.—The filter may be made either of dyed gelatine disks or dyed gelatine between optical flats. The former type is placed between the components of the lens, the latter fixed in front of the lens. Filters when used in aerial work are not required to give a tone rendering of colors equivalent to that seen with the naked eye, as usually is required in ground photography, but are used to eliminate the effect of haze.

The filter used in aerial photography permits the rays toward the red end of the spectrum to do their work by holding back all of the ultra-violet, part or all of the violet, and part of the blue, thereby neutralizing the powerful effect of haze. The shorter end of the spectrum being the most chemically active, when a filter is used the exposure must be increased as much longer as the filter is dark. In selecting filters the essential qualities are sharpness in cut of the short end of the spectrum and a low multiplication factor or filter effect.

Filter Factors.—The exposure necessary to produce a density of unity behind each filter is used for computing the increase of exposure required by the filter. These increases are known as the filter factors. By the factor of a filter is meant the number

of times the filter increases the exposure when used in conjunction with sensitive material of a certain speed. It can also be expressed as the increased time that the film, when it is being used, must be exposed when the filter in question is used than would be necessary to produce a normal negative without it. At this time a set of four filters is best suited for aerial photography, Aero 1,

U. S. Army Air Corps

FIG. 12.—OBLIQUE PHOTOGRAPH MADE IN HEAVY RAIN

An oblique photograph of the Capitol taken during the inaugural parade on March 4, 1929. An example of an oblique photograph made in a heavy rain, using an F/5.0 lens of 20-in. focal length and hypersensitized panchromatic film without a ray filter. The exposure was 1/75 of a second. The air speed of the airplane was reduced to 65 miles an hour. This picture, an oblique made with the quick-work process in daylight, shows the same area that is seen in the picture made of the Capitol at night, by flashlight.

Aero 2, Wratten 12, and Wratten 25. The strongest filters, 12, and 25, can be used only with the most sensitive material. The red filter can be used only under the very best conditions. Under other conditions lighter filters are necessary.

Plates and Film.—The ordinary photographic plate or film is sensitive to only the violet and blue rays of the spectrum. Some years ago, Wratten and Wainwright brought out an improved plate

that they called panchromatic. It is not only sensitive to the violet and blue rays, but is sensitive to practically the whole of the visible spectrum. Numerous improvements have since been made in the preparation of panchromatic film. Good results have been obtained by using material sensitized in an emulsion and hypersensitized by treatment with a bath of ammonia before

U. S. Army Air Corps

FIG. 13.—PHOTOGRAPH MADE IN LATE AFTERNOON AND DEVELOPED IN AIRPLANE

This is a picture of the Capitol from an elevation of 2,000 ft., using the quick-work photographic method, whereby the photograph is finished in the airplane in eight minutes from the time it is snapped. This picture also illustrates the advantage of using fast panchromatic film, since the exposure was made at 4:30 in the afternoon, as evidenced by the long shadow of the Capitol dome, whereas a picture made on ordinary film would have been hopelessly under-exposed at that time of day. It is possible in the summertime, with such film, to make photographs as late as 5:30 in the evening or even six o'clock under favorable weather conditions.

use. If red filters are used, hypersensitizing with ammonia gives excellent results. Hypersensitized film gives negatives so superior to those obtained from other types of film that it should be used in most aerial photographic work.

In very bright sunlight, materials having a working speed (with filter) of approximately 17 can be used effectively. Aerial

film must have sufficient speed to be used at 1/150 of a second near the ground, and 1/100 to 1/50 of a second at higher altitudes. Film with less speed than panchromatic cannot generally be used.

A new film known as kryptocyanine has been developed for taking photographs through haze and a minimum degree of fog. Remarkable results have been obtained due to the haze-penetrating qualities of this film. It is not sensitive to the blue rays reflected from the haze. It is sensitive to the infra red end of the spectrum. Use of this film will do much for the future of high altitude photography. The Japanese claim to have a film, which by use of the infra red rays, enables them to take a picture in rain or dense fog.

Film vs. Plates.—The weight of film is 1/15 that of plates. It requires much less space. The magazine is easier to operate and not so bulky. The one advantage that plates have is that they do not shrink or expand during developing or drying, but excepting special cases the many points in favor of film will warrant its use rather than the use of plates.

CHAPTER III

OBLIQUES OR AIR VIEWS

AERIAL photographs taken at an angle between the horizontal and vertically down are termed obliques or air views. Obliques produce a perspective with which every one is familiar, resembling

U. S. Army Air Corps

FIG. 14.—OBLIQUE MOUNTAIN VIEW

Mount Moran in the range of the Teton Mountains just south of Yellowstone National Park. The higher peaks of this range, some 13,500 ft. in height, have recently been added to the Yellowstone Park reservation. This photograph was made from an elevation of 12,000 ft. with a K-6 camera.

somewhat a picture of the lowlands taken from a mountain. When taking obliques there are several factors that can be controlled. These factors are: (1) the composition of the photograph; (2) the exposure given; and (3) the size of the stop used.

By the proper manipulation of these factors a picture can be obtained that is equal, photographically, to a ground view.

Composition.—By careful study and selection of the position from which the picture is to be taken a much more effective view can be obtained than by haphazard snapping of objects as the plane flies by. The points to be considered in selecting the position are: (1) the size of the object as it is to appear in the picture; (2) the most effective view of the subject; (3) the area to be included in the picture; and (4) the shadows.

The first requisite is controlled by the distance of the camera from the object. The more distant the object is from the camera the smaller it will appear in the photograph. The size of the object also depends upon the focal length of the lens used. A lens of longer focal length will give a larger scale, that is, larger objects, but will cover a smaller area than a lens of shorter focal length. For example, at a given altitude a lens of 10-in. focal length will cover four times the ground area that could be covered by a lens of 20 in., but the scale, that is, the size of objects on the photograph, will be half that of the picture taken with the 20-in. lens.

Again, the most effective view of the subject can be obtained only by making a study of that subject from the air. By flying in a circle around the object or view a study can be made from all angles. An experienced aerial photographer can select the desired view on the first circle but he must have an accurate knowledge of the area that will be covered by the camera that is being used. As the desired view is reached the pilot is given a predetermined signal. The important features to be emphasized should be taken in the foreground of the view.

Third, the area to be covered is controlled by the altitude from which the picture is taken, as well as by the focal length of the lens, the size of the plate or film, and the angle at which the picture is taken. It is usually best to include only a small area surrounding the object, but this of course depends upon the purpose for which the picture is to be used.

Fourth, the length of the shadows has a great effect upon the appearance of an aerial view. Shadows are dependent, of course, on the time of the year and day. Obliques should generally be taken between the hours of 10 a.m. and 2 p.m. except when a certain artistic effect may be desired.

GROUND AREA COVERED BY OBLIQUE PHOTOGRAPHS

(With camera 20 deg. from horizontal)

A = horizontal distance from camera to near edge of photograph
B = length of area covered
C = near width of area covered
D = far width of area covered

Size of Plate	7×9 in.				7×9 in.			
Focal Length	10-in.				20-in.			
Altitude, Feet	A	B	C	D	A	B	C	D
1,500	1,911	43,542	2,157	40,224	2,649	5,565	1,425	3,873
2,250	2,865	65,286	3,234	60,435	3,972	8,346	2,100	5,760
3,000	3,824	87,089	4,311	80,459	5,298	11,136	2,799	7,680
3,750	4,776	118,858	5,400	100,566	6,624	13,908	3,498	9,600
4,500	5,733	130,649	6,47.	120,668	7,950	16,698	4,200	11,520
5,250	6,687	152,403	7,554	140,793	9,276	19,688	4,899	13,440
7,500	7,644	174,174	8,631	160,900	10,602	22,275	5,598	15,360
6,000	8,598	195,195	9,708	181,020	11,928	25,068	6,300	17,280
6,750	9,555	217,716	10,785	201,135	13,254	27,858	6,999	19,200
8,250	10,509	239,470	11,862	221,256	14,580	30,648	7,698	21,120
9,000	11,463	261,264	12,939	241,362	15,924	33,458	8,400	23,040
9,750	12,420	283,035	14,016	261,477	17,256	36,228	9,099	24,960
10,500	13,374	304,806	15,093	281,589	18,576	39,018	9,789	26,880

Exposure.—The length of exposure that can be given depends upon: (1) the speed of the sensitized material used; (2) the time of the year and of the day; (3) the kind of day (clear or overcast); (4) the factor of the filter if one is used; (5) the size of the aperture or stop used; and (6) the speed and vibration of the plane at the time of exposure.

The most satisfactory results can usually be obtained by using a very fast plate or film, setting the shutter speed so as to stop blurring caused by motion and vibration (usually 1/150 of a second). Then, if excess exposure remains, stop down the lens to bring the exposure to normal. Filters are not generally used in taking

obliques from low altitudes. Under normal conditions the filter will not be necessary unless the altitude from which the picture

U. S. Army Air Corps

FIG. 15.—OBLIQUE OF GRAND CANYON

The lower depths of the Grand Canyon of the Colorado River, made from an Army Observation Airplane with a K-6 camera.

is taken is over 1,500 ft. or unless the angle of view includes the horizon.

Stops.—The photographer should possess a thorough knowledge of the light strength of his lens, when it is stopped down as well as when it is being used at full aperture. While aerial photography is usually done at full aperture, if the photographer is familiar with the exposure time and stops he possesses the great advantage of being able to work with stops when possible, thus obtaining considerably better general and rim-sharp pictures.

Stops are used to reduce the aberrations caused by light rays which arrive at the marginal zones of the lens, by excluding them from action upon the photographic plate or film. Generally speaking, the quantity of light admitted to the camera will be proportional to the square of the diameter of the diaphragm aperture. The diaphragm should be placed between the lens components. If the diaphragm is placed in front of the lens barrel distortion may result. If placed behind the lens pin cushion distortion may result.

General Information for Taking Obliques.—In the forenoon the chemical effect of light is generally greater than in the afternoon as during the night the water vapor is almost always low. Humidity and barometric pressure have a strong effect upon the chemical power of light.

When it is hazy an oblique should be taken as nearly vertically downward as possible.

While an exposure is being made the pilot should not change the direction of flight.

The shutter must always have sufficient speed to eliminate blurring from vibration. Even though the airplane is not moving over the ground (when heading into a strong wind) the shutter speed will have to be from 1/100 to 1/150 of a second in order to eliminate the effect of vibration. Vibration is a more significant cause of blurring than the ground speed of the plane.

Obliques of cities can best be obtained when the sun is at its zenith. Shadows cast by a rising or a setting sun will reduce the amount of detail that can be recorded.

Exposures made directly into the sun will give a flat negative especially toward the upper side of the picture.

The vibration of the airplane must either be taken up by the camera mount or by the body of the operator. The trigger to the shutter should be snapped in the same manner as in firing a gun, that is, with a steady, even pull instead of a jerk or a push.

If a vacuum-back camera is used, the speed of the plane must be great enough to create the required suction to keep the film in a focal plane.

When taking obliques over thickly populated districts, especially where there are no landing fields, it is much better to use a 20-in. lens. The longer focal length allows the flight to be made at a higher altitude while still retaining the same scale picture.

Photo by Hamilton Rice Expedition

FIG. 16.—HARBOR OF RIO DE JANEIRO

An aerial photograph, from 2,000-ft. elevation, of Rio de Janeiro, whose harbor is perhaps the most beautiful in the world.

Continued flying and throttling the motor at low altitudes over the city will eventually end with disaster.

Flying and Taking Obliques.—To take an oblique or air view the photographer first decides the point from which the picture is to be taken. The pilot then flies past the object over the selected point at the desired altitude and with the sun at the photographer's back if possible. The pilot reduces the speed of the plane to minimum flying speed, placing his ship in a slight glide just before reaching the objective. The photographer, having already pre-

pared the camera for an exposure, aims it at the ground at the approximate angle at which the picture is to be taken, being certain not to include any portion of the airplane in the angle of view. As the object to be taken is reached the camera is so adjusted as to bring into the view finder the exact view desired. As this is done the back of the camera must be parallel with the ground regardless of the position of the ship. The horizon will assist the photographer in leveling his camera. The picture is then taken and the camera prepared for the next exposure.

CHAPTER IV

INSTRUMENTS USED IN NAVIGATION [1]

THE accuracy of a photographic flight will depend to a great extent upon the navigation instruments used. The value of these instruments to the pilot is proportional to his knowledge of their inaccuracies as well as of their use.

The selection of navigation instruments for a photographic flight depends upon the amount of navigating necessary to perform that flight. The number of identifiable objects along the strips composing the area to be mapped, the length of the strips, and the information that can be gained from the available flight map govern the amount of navigation that will be necessary on each flight. The compass and altimeter are used on all flights. Both instruments are subject to a number of inaccuracies. The extent to which they can be depended upon, therefore, must be thoroughly known to the pilot. Alignment by compass bearing will often be off five degrees. The earth inductor compass is accurate to within one degree, and precision of a gyropilot director for the brief time of alignment before starting a strip is even greater; thus by combining the use of these three instruments a much more accurate course can be flown than would be the case if only the compass were used. It is recommended that on all photographic missions the gyro-turn indicator be used in connection with the compass. On long navigation flights over poorly marked strips the earth inductor compass should also be included. The statiscope will help to maintain a constant altitude. This instrument is not subject to the amount of lag found in altimeters and therefore will indicate a change in altitude much faster than the altimeter.

[1] The study of aircraft instruments, of primary importance in aerial photography, has generally been neglected as a factor in accurate flying.

ALTIMETERS

Altimeters measure and record the elevation above sea level or above the ground from which the ascension is made. The accuracy with which they are constructed usually depends upon the type of work for which they will be used. For aerial photography, elevation above the ground is desired within as close a limit as possible. It is also necessary that the scale of the altimeter used for aerial photography be of sufficient size to be easily read as it is often necessary to record the altitude after each exposure.

The most common type of altimeter is constructed on the principle of the aneroid barometer. The dial is graduated in units of height to conform to a standard pressure altitude formula. The pressure-sensitive element is an evacuated box having flexible sides. This box is called an aneroid. The motion of the aneroid is increased by levers and is transmitted through a chain or metallic ribbon to the pointer.

Adjustment.—It is usually desirable that the instrument read zero on the ground from which the ascension is made. As barometric pressure changes from day to day it has been necessary to provide for either shifting the mechanism or scale so that the pointer will indicate zero before each flight. For this purpose a knob is usually provided so that the pointer can be brought to zero. If the starting point is above sea level, and the altitude of the flying field above sea level is known, the altimeter may be used to indicate either the altitude above the flying field or the altitude above sea level. If the divisions on the dial are uniform no error is introduced by shifting the scale.

Altimeter Errors.—The first error to be considered is that of "creep" which is due to the inability of the elastic elements to follow sudden changes of pressure. Usually after a fast descent to the starting point, at which the altimeter should read zero, the altimeter will read several hundred feet too high, several minutes being required for the pointer to return to zero. When ascending, the tendency is for the altimeter to indicate a reading lower than the actual height, and higher upon descending. The amount of this error depends upon the rate of ascent or descent.

The zero error is due to variations in barometric pressure not only on the ground but at various altitudes. In the present type of pressure altimeter this error is usually eliminated.

Temperature errors make the altimeter somewhat inaccurate especially in cold weather at high altitudes. For ordinary purposes these errors are usually neglected, but in certain types of photographic work they cannot be overlooked.

Installation of Altimeters.—The altimeter being a complete unit within itself, its installation is simple compared with that of some of the other instruments. The only point to be observed is that of leaving the air hole open in the case which is located just under the zero adjusting knob, so that the pressure in the case will be equal to that of the air through which the aircraft is flying.

AIR SPEED INDICATORS

This instrument shows the relative speed of the airplane through the air. In still air this speed would be practically the ground speed. When the plane is traveling with the wind the ground speed is approximately the sum of the air speed plus the speed of the wind. If the plane is traveling against the wind, the ground speed is air speed less the wind speed. If the plane is traveling several hundred feet above sea level, a correction must be made to obtain the true air speed. Roughly, 2 per cent of the indicated reading should be added for each thousand feet above sea level. Generally, the indicated air speed is less than the true speed, except when flying near sea level during cold weather with high barometric pressure when the air speed indicated will be too high. In photographic flying the most useful function of the air speed indicator is to determine the best climbing angle and the most economical speed for straight flying.

Errors in Air Speed Indicators.—The most common errors are those due to leaky connections, error of calibration, excessive friction, and moisture. These errors should not exceed three miles per hour at any point on the scale. It will be observed that some instruments greatly exceed this error.

COMPASSES

The compass is used as an instrument of navigation for cross-country flying, bombing, and photography. Only when the magnetic compass has been properly compensated for its position in the aircraft used, and where its action is thoroughly understood, will it serve the above purposes. When navigating with a compass

it can be used to indicate the heading of an aircraft, establishing fixed lines as a reference for other observations, measuring drift, and determining track.

Terrestrial Magnetism.—The earth acts as a magnet with one pole near the North geographic pole and the other near the South geographic pole. If a bar magnet is so suspended as to turn in any direction about its center of gravity it will take a position with one end pointing toward the North magnetic pole and the other end pointing toward the South magnetic pole. Since the north end is equal to the south end, only the north is considered. This position taken by the aforementioned bar magnet gives the direction of the magnetic force. At the magnetic North pole the needle would be vertical with the north end down; at the magnetic South pole the needle would be vertical with the south end down. At intermediate positions near the equator the needle will take a horizontal position. An imaginary line connecting the points where the needle takes this horizontal position is termed the magnetic equator. Between the magnetic equator and the magnetic poles the needle makes an angle with the horizontal. This angle is called the "dip" of a compass.

An aircraft compass is actuated by a bar magnet or a set of bar magnets held parallel to one another in a common frame. The frame is pivoted at a point above its center of mass so that only the horizontal component of the earth's magnetism will direct the pointing of the magnet. Aircraft magnetic compasses are classified as vertical card and flat card, with the vertical card divided into two classes, upright and inverted. In both types of the vertical card compass, the card is viewed from the side. The flat card compass is read from above. For most aerial work, including photography, the vertical card type is the most convenient.

Type B-3 U. S. Air Corps Standard Compass.—The following description of the type B–3 compass will serve as a good example of the vertical card compass.

The card is $2\frac{1}{2}$ in. in diameter and carries two cylindrical bar magnets mounted on the under side of the card. The outer rim of the card is marked in 10-deg. graduations. The cardinal points are indicated by letters *N*, *E*, *S*, and *W*. The divisions of 30 deg. are numbered clockwise. The card is direct reading, that is, *N* on the card is 180 deg. from the north end of the magnets.

From the center of the card a pivot extends downward, the card resting in a jewel cup at the top of a post extending from the bottom of the bowl. The card is kept in place by a cage and hemisphere forming a retaining device preventing the pivot from leaving the cup. The vertical lubber line is mounted inside of the bowl close to the glass face. A horizontal cross line is attached to the lubber line giving a reference for the position of the card on a bank or side slip, thereby making the compass useful as a lateral inclinometer. The damping system consists of two parts: a liquid which fills the bowl in which the card is submerged, and a mechanical device of springs and cushions which absorbs the vibration. The liquid used in this type of compass is kerosene but that used in some of the other types is a mixture of water and alcohol.

Installation of Compasses.—While it is practically impossible to lay down a set of standard rules to cover each case of installation, careful investigation for each type of aircraft must be made. Following are some general directions:

1. The instrument should be mounted as near the pilot's line of vision as possible. Steering a course solely by compass is very tiring and difficult.

2. The compass should be placed where the magnetic field is least affected by local magnetism. The force of a magnetic field is inversely proportional to the square of the distance from the magnet.

3. The compass should be mounted so that a plane passing through the pivot post and lubber line is parallel to the fore and aft sections of the axis of the aircraft.

4. The compass must always be handled carefully—rough treatment may dull the pivot point or break the jewel cup.

5. The compass should be fastened in place with brass screws, bolts, nuts, etc. Iron should not be used because it has a strong magnetic effect.

6. The compass should be compensated, and the deviations for the compass, mounted in the aircraft which is used, should be printed on a card and placed near the instrument.

Errors in Compasses.—The inaccuracy in compasses arises from four causes:

1. Permanent and residual magnetic fields of the steel parts in the aircraft.

2. Magnetism in the soft iron induced by the earth's magnetic field.

3. Vibration.

4. The turning motion of the aircraft.

Errors due to the first and second causes may be eliminated for the most part by compensation; those resulting from the third cause are avoided by suitable construction; but there is apparently no way to eliminate the fourth type of error. While subject to jarring or vibration in being forged, machined, or fitted in place, the steel parts of an aircraft acquire a certain amount of permanent magnetism induced by the earth's magnetic field. On account of the vibration of the engine and the shocks in landing, this permanent magnetism will change after the aircraft is put in service. However, a certain amount will always exist. The resultant field of permanent magnetism causes the compass needle to deviate from the magnetic north. The amount and direction of this deviation depend upon the angle which the permanent magnetic field of the aircraft makes with the magnetic meridian. The deviation due to permanent magnetism changes sign every 180 deg. in the change of direction of permanent magnetism and for this reason is termed "semicircular" deviation.

Among the serious errors of compasses used in aircraft is the error that occurs when turning from a north course. This error is called the "northerly turning error." It is due to the vertical component of the earth's magnetic field and cannot be entirely overcome. When an aircraft is flying northward and makes a properly banked turn to the east or west the card no longer remains horizontal, but tips with the aircraft, at the same time keeping parallel to the floor. This is caused by the centrifugal force developed by the turn. With the card in this position the earth's magnetic field is allowed to act. The north end of the card tends to turn downward. When a slow, flat turn is made the card will remain horizontal and hold its direction. In this case, the aircraft and the lubber line turn with reference to the card. But on a banked turn from a northerly course the card turns also and in the same direction as the craft. The rate of turn of both card and aircraft may be the same. Therefore if the pilot depends upon the compass alone the airplane will not appear to be turning at all. The compass may turn faster than the airplane. In this case the effect is that the craft seems to be turning in a direction

opposite to the actual turn. Then again, the compass may turn slower than the craft. In this case the direction of the turn will be shown correctly, but the rate of turn will be faster than it appears. When turning from an easterly or westerly course this effect does not occur. When turning off a southerly course the card tends to turn in a direction opposite to that of the aircraft. The aircraft, therefore, appears to be turning faster than it actually is. This makes it necessary for the pilot to use some fixed point of reference or other instrument to straighten out his course and hold the craft level until he can obtain a correct compass reading.

The period of a compass is determined by the strength of the card magnets. A short-period compass has strong magnets. A long-period compass has weak magnets. The northerly turning error for a compass with a period of 10 to 15 seconds causes the card to turn at a rate greater than the aircraft, while that for a compass with a period of 40 to 50 seconds causes the card to turn at a rate less than the aircraft. A long-period compass would be better for cloud flying if it were not so sluggish in registering turns. It is therefore better to use a short-period compass and to equip the craft with a turn indicator. This instrument indicates a turn independent of the compass and enables the pilot to hold a straight course or to straighten out from a turn.

Compensation of Airplane Compasses.—The process of compensating compasses on aircraft and of obtaining the deviation at various points is called "swinging the ship." For this purpose every flying field should be equipped with a circular concrete platform which has a radius of at least the length of the largest airplane to be swung. The platform should not be nearer than 75 yd. to any other aircraft and should be at least 100 yd. from any steel structure. Starting with the magnetic north the radii should be laid out every 30 deg., using a dolly to elevate the tail-skid. The airplane being in about flying position, the dolly must be strong enough to hold an airplane with the engine running at half throttle. There should be a pair of wheel blocks. It may also be necessary to use a couple of 50-lb. sand bags to put across the tail if the ship is nose heavy. The procedure is as follows:

Procedure 1:

1. Elevate the tail on the dolly until the ship is in flying position.

2. If necessary, place the sand bags across the tail of the ship.
3. Place the center of the landing gear over the center of the swinging base.
4. See that there is no lateral inclination of the airplane.
5. Head the airplane north by sighting along the fuselage and the north and south line and by checking along the wheels or the leading edge of the wing against the east and west line.
6. Block the wheels, start the motor, run at about half throttle.
7. See that all steel and iron parts are placed for flight. This will include photographic equipment. If the control column is made of metal, it should be held in neutral position at each setting.
8. Empty the compensating chambers of all magnets. Keep all unused corrector magnets at at least one and a half feet from the compass during operations.
9. For the first compensation place the airplane with the longitudinal axis on the magnetic meridian, that is, with the fore and aft axis parallel to the north and south line. Usually with each compass are furnished three sizes of compensating magnets: 1/32, 1/16, and 3/32 in. in diameter. Their strength is roughly proportional to the diameter. Place a sufficient number of these magnets into the compensating chamber, which is at right angles to the magnetic meridian, in order to reduce to zero the easterly or westerly deviation. Then set the airplane along the east-west line and correct the northerly and southerly deviations by placing magnets in the compensating chamber which is at right angles to the first compensating chamber. The deviation for this position is generally greater than for the north and south heading. If the compass is near the engine so many magnets may be required that the use of an extra compensating chamber below the compass may be necessary. Having corrected the deviations for the two-point, the semicircular deviations for all points should be nearly or entirely eliminated. If no further compensation is desired determine the remaining deviations by placing the airplane on the north and south line with the nose north, then on the 30-deg. line, then on the 60-deg., and so on around the complete 360 deg. of the circle. At each point note and record the

reading of the compass card in degrees. Prepare a table giving the compass reading for each of these points.

Procedure 2: Another method of heading the airplane on the magnetic bearings can be used when it is impracticable to lay out these points on the ground:

1. Suspend a reliable compass, preferably a large flat card type, from a point near the wing tip (either side).
2. Elevate the tail of the plane and proceed as directed in the first adjustment, using the master compass to obtain each heading.

Notes on Swinging Compasses:

1. See that there is no undue friction on the pivots. This may be ascertained by causing the card to deflect through a small angle and noting whether it returns freely to its original position. See that the compass is properly filled with damping fluid. Make sure that the lubber line is parallel to the fore and aft axis of the ship.
2. Place all magnetic material in flying position.
3. Remove the old compensating magnets from the chambers.
4. Never take readings when any other aircraft is within 75 yd.
5. Avoid parallax when reading.
6. To obtain reliability, check the airplane before each mapping project.

Repair and Inspection of Compasses.—If the compass card is sluggish or tends to stick, examination should be made for a cracked jewel, dirt in the jewel cup, damaged pivot, or weak magnetic needles. The magnetic needles may become displaced and cause the card to become unbalanced. Weak magnets should be replaced by new ones. Luminous paint should be applied according to directions specified for each brand of paint. When filling the bowl, the gaskets should all be sealed with shellac and dried for at least twenty-four hours after assembling. Then the bowl may be filled with water and white, acid-free, kerosene. Filling can best be accomplished by siphoning through a rubber tube and a small glass or metal nozzle.

Before being placed in service the instrument should be inspected for the following points:

1. Leakage.
2. Tipping—The card assembly should be clear when the compass is tipped in any direction 20 deg. from the vertical.
3. The liquid should be clear and colorless.
4. The card should be clean.
5. The lubber line should be tight and aligned.
6. Each shock absorber should carry its own load and be centered.
7. All nuts should be locked and tight.

Earth Inductor Compass.—The Earth Inductor Compass is essentially a magnetic compass differing from the conventional type in that it has no needle employed to detect the earth's field. The Earth Inductor Compass consists of three main parts:

1. The generator.
2. The controller.
3. The indicator.

A coil of wire, the plane of which is vertical, is rotated around a vertical axis, this taking the place of a magnetic needle in an ordinary compass. The two ends of the coil terminate in diametrically opposite segments of a simple commutator. At the instant when the plane of the rotating coil is parallel to the lines of force of the earth's magnetism, a maximum difference of potential is induced between the coils to the commutator segments. The polarity of this potential depends both upon the direction of the rotation of the coil and upon the relative direction of the earth's magnetic field. If the diametrically opposite brushes are in contact with the commutator segments of the coil when the plane of the rotating coil is in position, a large deflection of the galvanometer occurs. If the brushes are so set that they complete the circuit of the coil and the indicator the instant that the plane of the coil is at right angles to the earth's magnetic lines of force, no current flows because no potential is being induced at that instant, the indicator pointer remaining at zero. If while the coil continues to rotate, the brushes are turned slightly from the latter position, a small deflection of the pointer will occur each time the brushes come in contact with the segments.

The indicator pointer will deflect either way from zero, depending upon the direction of the horizontal component of the earth's

magnetism relative to the vertical plane which the coil is passing at the instant when the brushes are in contact with its commutator segments. If the setting of the brushes is made with reference to a datum line on their mounting, this device is a means for showing the direction of that datum line with reference to the earth's magnetic field. The earth inductor compass, therefore, can be mounted on an aircraft to show its direction or heading. The currents generated by the device described are intermittent. The flickering of the pointer which is produced is practically eliminated by having several coils, each with its own pair of segments on the commutator.

There is but one pair of brushes, each of which connects with the indicator. The generator by its own rotation is afforded gyroscopic stabilization. The brushes are set relative to the fore and aft axis of the airplane by means of the controller, which is connected to the generator through a rigid shafting. The ratio between the controller dial and the large gear that turns the brushes is 36 : 1. The shaft is connected directly to the inside dial. The gearing between the inside dial and the outside dial is also 36 : 1. Thus one turn of the dial (inside) by means of the handle attached rotates both the brushes and the outside dial 10 deg. When installed the brushes are so adjusted that their position which is controlled by the dials represents the airplane's heading. The indicator is connected to the brushes by wires. The pointer stands at zero when the course is being properly flown, and will swing to the left or right when the aircraft has flown off its course. The indicator also points to zero when the airplane is flown on a course of 180 deg. from that set to be flown. In this case a turn to the right or left causes the pointer to deflect to the left and vice versa.

BANK AND TURN INDICATORS

Inclinometers (Bank Indicators).—These instruments are used to indicate whether the aircraft is properly banked on a turn and the inclination of the aircraft to the horizontal or vertical. Types using a bubble, ball, liquid, pendulum, and various combinations of these devices are used to indicate whether the aircraft is properly banked.

In photography, where it is necessary to measure the exact bank, simple inclinometers are not reliable, due to the effect of

accelerations. Gyroscopes, or gyropendulums, are best for this purpose.

Turn Indicators.—As the name implies, the turn indicator is used to indicate any turn of the aircraft in a horizontal plane. This instrument is used to check a compass as mentioned under compasses. A compass cannot be relied upon to show the process of a turn, especially on a northerly course. The turn indicator helps to supply all the necessary data not furnished by other standard navigation instruments nor by the normal senses of the pilot. The turn indicator enables the pilot to fly a straight course, to turn from an old course to a new, and at all times to keep the aircraft on an even keel. When used in conjunction with a compass it is one of the most useful instruments used in photographic work. The two most successful types of turn indicators are the static head and the gyrostatic.

Static Head Type.—This type of indicator has been used considerably by the British. From the indicator on the instrument board two lines of tubing lead toward the wing tips, one on the right and one on the left. The outer end of each tube ends in a static head; the forward end is closed by a bullet nose. There are a number of fine holes drilled through the side of the tube about two inches back of the nose. On a turn the centrifugal force on the air in the outer wing tubing is greater than the centrifugal force on the air in the inner wing tubing. More air is forced out through the static head on the outer wing and the pressure in the tube on that side is less than the pressure on the inner. This difference in pressure causes the pointer on the indicator to move. The static heads, in order to operate correctly, must be mounted exactly parallel to each other and parallel to the line of flight. It is better to have the heads mounted on swivels with vanes. They then automatically take the direction of the line of flight. When mounted on the outer struts this indicator shows a side slip (always in a straight line) as a turn in the direction of the side slip. This error is removed when the static heads are mounted two feet above and one foot in advance of the upper wing. This mounting is not entirely practical and if the error is known and understood it is of little consequence since the pilot, by sensing the side wind, can always distinguish a side slip from a turn. This indicator will detect a turn at the rate of 2 deg. per minute.

Gyrostatic Turn Indicator.—This type is much simpler and more rugged. The gyrostat is mounted on a horizontal axis in a gimbal which in turn is mounted on the frame. The pointer is mounted on the shaft of the gimbal. The axis of the spin is athwartship and the direction of the spin such that the upper rim moves toward the nose of the aircraft. The axis of the gimbal is parallel to the longitudinal axis of the aircraft. The gyrostat is driven by an air jet. The case is airtight except for an inlet to the jet and an outlet tube which is connected with a double or single Venturi tube mounted in the slip stream. If the air is drawn out of the case by the action of the Venturi tube air is forced in by the atmospheric pressure through the inlet nozzle. The coil spring tends to keep the axis of the spin horizontal. When an aircraft turns to the right a torque is exerted which causes the right end of the spin axis to turn upward. This torque is opposed by the coil spring. As soon as the turning of the aircraft stops, the action of the coil spring returns the gyrostat to zero position. When the turn is to the left the spin axis is tipped in the opposite direction, the torque, acting on the spin axis, is proportional to the rate of turn of the aircraft. The instrument shows both properly banked turns and skidded turns. Since the tipping of the spin axis of the gyrostat is opposite to the bank of the aircraft on a turn the instrument is very sensitive. If an aircraft is banked without turning, as in a side slip, the indicator is not affected. Since the aircraft is generally slightly turned upon going into a side slip, the indicator first shows a turn and then returns to a zero position. Since the gyrostat of the turn indicator is operated by the suction of a Venturi tube its speed of rotation varies with the speed of the aircraft.

STATISCOPES

The statiscope is used to aid the pilot in holding the aircraft at a constant elevation. It is more sensitive than an altimeter and it will register very small changes in pressure. The most common type of statiscope consists of a sensitive manometer and a thermally insulated chamber. A small thermos bottle is used in some statiscopes. There are two outlets to this bottle: one connects with the manometer and the other with the outside atmosphere through a small valve or petcock. The manometer tube

is rather short and ends in a flared portion which acts as a trap. This trap prevents the liquid from escaping either into the air chamber or to the outside atmosphere. The liquid must have a low density and a low vapor pressure and its viscosity must not be excessive at low temperatures. The valve is left open until the altitude is reached at which it is desired to maintain level flight. When the valve is closed and the aircraft starts to descend, the pressure of the outside atmosphere becomes greater than that in the thermos bottle causing the liquid to travel toward the bottle. As the aircraft continues to descend, the liquid is pushed farther into the enlarged section of the gage, allowing the air to flow past and thus equalize the pressure between the inside and outside air. As soon as the bubble breaks the liquid flows back into the restricted part of the manometer and forms another bubble. The above operation is repeated until the craft ceases to descend. If the craft ascends, the bubble moves in the other direction. In some cases a change of 10 ft. causes the bubble to break. To maintain a level flight the bubble is held in the center of the tube. The object in using a thermos bottle is to keep the air as nearly as possible at a constant temperature. If the temperature of the air in the thermos bottle increases slightly, while an attempt is being made to maintain level flight, the air in the bottle expands and pushes the liquid toward the outside atmosphere. In this case the same reading is given as though the airplane were ascending. The rate at which the airplane is ascending or descending can be measured by counting the bubble breaks per minute.

There are statiscopes which work on the same principle as the one just described but which use, instead of a liquid manometer, a mechanical manometer. In this type a thin diaphragm is used as the pressure-sensitive element. Its motion is magnified and transmitted to a pointer. Care must be taken of this type of statiscope to prevent its being subjected to excessive pressure.

CLIMB INDICATORS, SPEED AND DRIFT METERS

Rate-of-Climb Indicators.—Rate-of-climb indicators are used to indicate the rate of ascent and descent of an aircraft. They are most useful for determining whether an airplane is climbing at its maximum rate or, if the engine stops, whether the aircraft is descending at its maximum rate.

Ground Speed and Drift Meters.—This instrument can be used to find the strength and direction of the wind at the survey height and to calculate from this the bearing on which the airplane should fly. The time intervals which should elapse between photographic exposures can also be determined by this instrument. To use this instrument the pilot flies at a given speed on a given bearing by the compass, noting some point on the ground which passes directly beneath him, watches this point until it has been left some distance behind, and then, using his sights, swings the ruler until the point lies upon a vertical plane passing through it. The most convenient way of setting the ruler parallel to the direction of motion over the ground is called "taking a tail bearing."

Pioneer Drift Meter.—A ground speed and drift meter is to-day available in the Pioneer Drift Meter. The instrument consists of a base plate, for fastening to the aircraft, and a mount which fits into this plate. The mount carries a circular scale marked in degrees, a swiveled and cushioned eyepiece, and an arm bearing a vane. This vane can be set along the arm for taking observations from the front of the aircraft, or set at right angles to the arm for taking observations at the side of the aircraft. The vane is graduated for altitude settings and distance readings. A slider is provided which can be moved along the vane to give a reference line. The ground is observed through the eyepiece (to obtain drift) and the vane so rotated around the vertical axis that objects on the ground appear to travel along the wire. The angle of drift is then read on the scale. To obtain the ground speed, the slider is moved along the vane until the cross-wire is at the figure corresponding to the altitude at which the craft is flying. Looking through the eyepiece the distance seen on the ground between the two cross-wires is that marked on the side of the vane, either 4/10 mile or 1 mile. With a watch the time of passage of an object from one wire to another is noted. Reference to a table which is furnished with the instrument gives the corresponding speed in miles per hour. Special stop watches with dials graduated to read directly in miles per hour may be used.

Sperry Drift Set.—The drift indicator, or corrector, known as the Sperry Drift Set, is also called by them a synchronized drift set. It consists of two parts: a short prismatic telescope

of wide angle of vision, which has in the focal plane of the eyepiece a set of parallel cross-hairs (similar to the sighting wire of bearing plates) so mounted that they may be rotated about the axis of the telescope; the second part is a flat card compass with a movable lubber line. By means of a flexible cable the lubber line is turned about the compass card pivot through the same angle that the telescope tube is turned. It is intended that the compass shall be mounted in front of the pilot, whereas the telescope is used by the observer or photographer who sets off the angle of drift. The telescope is mounted in the craft so that the cross-hairs when set at zero on the circular scale are parallel to the fore and aft axis. Through the telescope, the photographer watches the apparent motion of some object on the ground and sets the cross-hair parallel to that motion. The pointer on the circular scale indicates the angle of drift, and at the same time the lubber line of the compass is moved through the same angle.

Webster Drift Sight.—A type of drift sight, very simple in construction and easy to use, has been devised by Capt. D. L. Webster. The form of sight may be varied considerably depending on the location of the pilot's cockpit and his line of vision over the lower wing, but the principle involved is the same in all forms.

There is a set of fixed radiating wires fastened to a triangular frame which is mounted outside of the lower wing and the fuselage. The wires are set at 10-deg. intervals and radiate forward and outward from the rear corner of the triangle, which is directly below the pilot's eye when he leans his head over the side of the airplane. In line with the wires there are lines painted on the wing. It would be an advantage to have these lines numbered in degrees. This sight should be placed on each side of the airplane so that the pilot may use the one on that side toward which he is drifting.

In estimating drift with this sight, the pilot looks for the wire or wires which appear to move least over the ground. For example, if an object on the ground does not cross the third wire but moves along it to the rear corner the drift is 30 deg. If objects cross one wire from left to right and the adjacent wire in the opposite direction the drift is some angle between the two. This must be estimated. In using this sight, as is the case with all drift sights, it is essential that the craft be kept flying in a straight line and on an even keel.

After the first estimate of the drift is made by sighting through the wires the pilot should check his measurement by sighting on an object farther ahead and watching for some time. For example, suppose he first judges the drift to be 27 deg. He then selects some object ahead of the wing, sighting along an imaginary line on the wing between the second and third lines corresponding to 27 deg. When the object appears behind the wing it should move directly to the rear corner of the triangle if the estimate is correct. If it does not, the pilot can judge how much he must change his first estimate. By this means a course may be steered within an accuracy of two degrees.

OTHER INSTRUMENTS

Le Prieur Navigraph.—This instrument is of French design. By its use it is possible to obtain, independently of the altitude and without computation or any auxiliary equipment as stop watch and computor, all the qualities desired, such as the drift, wind speed, wind direction, ground speed, and the course to steer for a given track. The navigraph makes use of the wind star principle, that is, any number of drift lines, plotted for the same number of different courses under constant conditions of wind speed, wind direction, and air speed, intersect in a point. This intersection has a definite relation to wind speed and direction and can be used to determine the values of both during flight. The apparatus consists essentially of two parts: the derivograph and the repeating disk. The derivograph is used to determine drift lines and to solve mechanically the vector diagram (wind star). The repeating disk is used to communicate the results to the pilot. The derivograph is fixed on the aircraft with its long side parallel to the longitudinal axis of the craft.

Pioneer Navigation Calculator.—This device is used to solve the wind star. The drift and ground speed are found on one heading. The speed and direction of the wind can be found and the calculator so set that the drift on any other heading will be known.

Barograph.—The barograph makes a continuous record of barometric pressure. In determining airplane performance barograph records are used in computing the altitude. The barograph contains a pressure-sensitive element, a magnifying and recording element, and a clock-driven drum.

The Gyroscopic Rudder Control.—The gyroscopic rudder control is still on the "doubtful list" but if it should prove successful it could relieve the pilot of a great amount of work, thereby increasing his efficiency and allowing him to give more attention to other duties.

The rudder is actuated by a wheel through a sensitive pneumatic relay and so keeps the airplane automatically on a straight course. Any slow turn, due to precision of the gyrostat wheel, can be corrected by the use of a lever control which adjusts the relation of the gyrostat wheel to the rudder. The gyroscopic rudder control should have a slow-motion adjustment so that the course can be altered relatively to the gyrostat wheel. When using the gyroscopic rudder control, the pilot must break the connection at the end of each strip and throw back into action after the airplane is flying straight and on the desired course.

The Strut Thermometer.—The strut thermometer is usually placed on one of the wing struts so as to be sufficiently far from the engine to be free from its temperature disturbances. This instrument must be graduated on a scale large enough to be read from the photographer's seat.

CHAPTER V

THE PHOTOGRAPHIC AIRPLANE

The most important item of equipment used in aerial photography is the airplane itself. The photographic results are closely related to the performance of the aircraft from which the pictures are taken. There is no existing airplane which possesses all the qualities essential to the ideal or model photographic aircraft, but an approach to this model craft may be made by observing as closely as possible the following requirements.

Motors.—The motor, or motors, should be the most reliable obtainable. They must run with all possible efficiency at all altitudes up to and including the service ceiling of the airplane. Some motors, it may be noted, retain their efficiency with changes of altitude much better than others. Some motors, furthermore, will miss or "cut out" when throttled down. There are often long intervals during which photographic mapping cannot be carried out. It is essential, therefore, that all equipment be in first-class condition when a good photographic day arrives. A large amount of aerial mapping is done over rough country with few if any landing fields available. Forced landings can be avoided only by using the most reliable motors and by careful and frequent inspections.

Take-Off and Landing.—Almost all aerial mapping is carried out away from the home station. It is frequently necessary to use small emergency fields. Very often the location of the flying field must be a primary consideration rather than the size of the field and the obstacles that surround it. First of all, the field must be accessible for supplies and as near as possible to the area which is to be mapped.[1]

The next consideration is a smooth field. This is important as the instruments may otherwise be thrown out of adjustment

[1] The flying field should not be farther distant from the area to be mapped than is necessary to reach the mapping altitude in a straight flight.

by a rough take-off or landing. From the foregoing it can be seen that the photographic airplane must take off and land in the shortest practicable distance. The landing gear should be so constructed that the wheels are interchangeable with pontoons. Possibly the requirements may lead eventually to the use of an amphibian.

Climb.—A high rate of climb at all altitudes up to the service ceiling is desirable. A slow-climbing craft will consume much valuable time in reaching the altitude at which the photographic work is to be carried out. This may call for the use of a supercharger which would not only increase the rate of climb at higher altitudes but would also increase the efficiency of the motor while photographing.

Service Ceiling.—The service ceiling is the highest altitude at which the airplane will perform with full, or almost full, efficiency with a working load.[1] The service ceiling for a photographic airplane should not be under 15,000 ft., with an absolute ceiling of about 18,000 ft.[2] Many mapping projects will demand that the flight be made at between 10,000 and 15,000 ft. altitude. At times it may be necessary to conduct photographic flights at this height above territory which is itself several thousand feet above sea level.

Stability.—It is of the utmost importance that the airplane should be stable at its cruising speed, the ideal being an airplane which could fly by itself. Such a machine, equipped with slow-motion adjustments on each control, enabling the airplane to be trimmed so that the controls could be abandoned, would still continue to fly straight at a constant speed with the wings level. These requirements should be approached as close as possible. It is practically impossible for the pilot to fly a passable photographic mission in a craft possessing stability below the highest standard. The closer that stability is approached in the photographic airplane, the more likely will the serious errors in photographic mapping be reduced.[3]

[1] The working load includes equipment, crew, full tank of gas and oil. Technically the service ceiling is the altitude at which the plane will still climb at the rate of 100 ft. per minute.

[2] The absolute or maximum ceiling for the photographic airplane has been placed at 18,000 ft. because a greater altitude capacity would cut down the load and fuel capacity essential to carrying out the photographic mission.

[3] See "Tilt," p. 237.

Vibration.—As will be seen under "Camera Mounts," vibration is one of the factors that must be overcome when taking aerial photographs. While the camera mount greatly reduces the serious effects of vibration, the mount alone cannot reduce vibration to the point where the pictures will not be blurred, if the airplane has excessive vibration.

Vibration is caused not only by the motor, but also by the effects incident to the flight of the aircraft through the air.

Visibility.—The photographic pilot not only must fly a straight course, but it is also necessary that the flight pass over objects on the ground course. The photographic mission will result in a complete failure if the ground course is not followed within very close limits. It can be readily understood why this cannot be done if the pilot fails to see the objects that he is to pass over. In conjunction with seeing the objects along the ground course, the pilot must be able to see the horizon. From the pilot's cockpit in the average airplane, it is practically impossible to see objects along the course on the ground, especially in a biplane, as the lower wing obstructs a large portion of his view of the ground. When fiying straight into the wind, the motor and the nose of the plane will hide the ground along the course to even a greater extent. A high-wing monoplane, therefore, will probably be the best suited for photographic work. A bi-motored monoplane of this type with the pilot seated in the front bay, or nose, would have a great many advantages not contained in any other type of airplane. Not only would the pilot's view of the ground be almost perfect, but also the addition of another motor would reduce the possibility of a forced landing. One of the disadvantages of this type is that it may prove to be more difficult for the pilot to make a level flight as the wings of an airplane are used in conjunction with the horizon in leveling.

Photographer's Cockpit.—The rear cockpits of most airplanes are so arranged that the photographic operator can function only with great difficulty. Flying, even under ideal conditions, is strenuous and fatiguing and to subject the photographer to unnecessary discomfort and crowded conditions will affect the efficiency of his work. The rear cockpit of a photographic plane should be so constructed that there is sufficient room for all necessary equipment and so proportioned that the photographer can move freely. The seat should be adjustable fore and aft and up

and down. It is important that the photographer be able to place himself in position so as to operate the camera with ease. The camera and view finder are the only instruments which will require floor space. It will be necessary for holes to be cut in the floor for each of these instruments, the diameter of the holes depending upon the type of instruments used. A cover should be provided for the camera hole. Conveniently arranged shelving should be built in the cockpit. This shelving will hold extra magazines and other necessary equipment.

A small shelf should be constructed on the side of the cockpit at the photographer's right. This shelf should be built so that it can be raised or lowered at the convenience of the photographer. It will hold an affixed writing pad and a self-filling pencil will be attached to the shelf by a chain.

Convenience and Comfort.—These are two important factors in photographic airplane construction which are often neglected. Aerial photographic mapping requires that the pilot and the photographer perform their duties with uniform efficiency throughout each flight. Uniform efficiency cannot be maintained if the pilot and photographer are subjected to excessive cold or fatigue which will be the case in open, cramped cockpits. It is recommended, therefore, that the airplane used be of the enclosed cabin type.

Signal Lights.—A system of signal lights should be installed for signals between the pilot's and photographer's cockpits. This system should be arranged so that it will be possible for either the pilot or photographer by pressing a button to light the lamps in the other's cockpit.

It is recommended that four lamps be connected at each end of the circuit in such a manner that if one lamp burns out the others will continue to light. The lamps should be located in the cockpits where they will, when lighted, easily attract attention.

General Specifications.—In summing up the foregoing requirements for a photographic mapping airplane, it is recommended that the following general type of airplane be used for this work: a high-wing, bi-motored, enclosed cabin monoplane equipped with a supercharger, slotted wings, and a landing gear which can be used either with wheels or pontoons.

The performance of the above airplane should be as follows: It should be able to take off with a full load and climb over a 30-ft. obstacle within 300 yd. Ten thousand feet altitude should

be reached within twenty minutes after the take-off. The cruising speed at that altitude should be about 100 miles per hour. The service ceiling should not be under 18,000 ft. The landing speed should be about 35 miles per hour while carrying 600 lb. useful load.

Airplanes for Taking Obliques.—While the airplane just described would be excellent for taking obliques, a much smaller and slower plane can be used just as effectively. The most essential factor is a reliable motor. It is also quite important that this plane have a comparatively low stalling speed. This plane should also be free from as many obstructions as possible

U. S. Army Air Corps

Fig. 17.—U. S. Army Air Corps Photographic Airplane

so the photographer will have a wide range when pointing the camera over the side of the cockpit without including any portion of the ship in the picture.

The Airship for Photographic Work.—While it is not economically possible at this time, or may not be in the future, to use the airship for commercial aerial photography, it is the ideal platform from which to take obliques. When taking obliques from an airship most of the difficulties encountered in an airplane are eliminated. By heading the airship into the wind, it can, for all practical purposes, be brought to zero ground speed. All vibration can be eliminated by cutting the motors. The small movement past the object is not sufficient for it to be taken into consideration. The airship can be flown at very low altitudes with much greater

safety than an airplane. One of the important factors is that the pilot and photographer can carry on a conversation in their natural tone of voice, this making it possible for the photographer to direct the pilot to the exact point from which the picture is to be taken. Due to the fact that vibration and movement need not be considered, any stop or exposure that can be given on the ground can be used in the airship. All these factors make the airship the ideal platform from which to take obliques.

CHAPTER VI

AERIAL CAMERAS

Although cameras used in the air are based on the same general principles as those of the ground camera there is considerable difference in the application of these principles and in the construction and operation of the camera. Most aerial cameras at this time have been constructed to meet military requirements. The majority of them are automatic or semi-automatic in operation. This is an important factor in the specification of a war camera but it has little, if any, value in a camera used for peace time mapping.

The time interval between exposures at 10,000 ft. when using a 12-in. focal length lens is from 22 to 35 seconds. This time interval allows ample time for the operator to prepare the camera by hand for the next exposure and to perform all other duties between exposures.

Manual preparation of the camera is a much surer method than relying on automatic or semi-automatic preparation, even though the vibrations of the automatic mechanism will inform the operator, when he has his hand on the magazine of the camera, whether the mechanism is working. If a connection should come loose just before the exposure, however, that exposure will be missed. When the pilot is flying the course by navigation it is a difficult undertaking to make a 360-deg. turn in order that the exposure just missed may be photographed. The most important reason, however, for recommending hand operation, is that when the camera is automatically operated the photographer cannot select the instant when the exposure is to be made. This will mean that he must endeavor to keep the camera approximately level for five seconds before each exposure, whereas, when the exposure is made by the operator himself it is possible for the exposure to be made at any time during the last three seconds before the elapse of the time interval and when the level bubble is centered.

The general specifications for an aerial camera are:

1. A fixed focus with the lens in a barrel mounting with sufficient length of threads on the barrel to permit the initial focusing and refocusing.

2. The camera body should be made as light and strong as possible. The body is usually constructed of aluminum.

3. The cones should be interchangeable.

4. The magazine should hold sufficient film for 100 exposures and should be fitted evenly and tight to the camera body, but the magazine should also be easy to attach and detach so that it may be removed and a new one replaced between the time intervals when flying a photographic mission.

5. The film must be held in a perfect focal plane during the time of exposure. This is usually accomplished by either a pressure plate or a vacuum back.

6. The pressure plate or other device must be constructed so that it will release its pressure on the film when the film is being wound over for the next exposure. If this is not done static may result and mar the picture.

7. A spacer should be provided so that only the proper amount of film for the next exposure is wound over, regardless of the size of the roll of film.

8. The shutter should be of a type that will cause the least distortion and should also not have a tendency to stick. The shutter should be equipped with speeds of 1/50, 1/100, and 1/150 of a second. The between-the-lens shutter when it will meet the two latter requirements will be the best as it produces less distortion than the focal plane shutter.

9. The camera should be well balanced when in a vertical position.

10. The following information should be registered on the film at each exposure: the position of the level bubble; the altimeter reading; the time and the number of the exposure taken. The importance of having these instruments register on the film is in the above order. All other data, as focal length, camera number, etc., can be recorded upon return to the ground.

11. The entire camera must be constructed of the best material and by expert workmen, that is, every part must be made and assembled with accuracy. For example, the level bubble and the focal plane must be in accord. In other words, when the level bubble is in the center the focal plane must be horizontal (not considering the effect of centrifugal force).

12. The horizontal indicator (level bubbles) should show a reading of tilt of $1\frac{1}{2}$ degree in any direction.

The Oblique Camera.—The mapping camera can be used to take oblique views by adding a view finder. It is also advisable to add a sun shade. It is best that the film be held in a focal plane by a pressure plate rather than by suction since when the airplane stalls to take an oblique view, the suction plate often does not function properly. It is usually advisable to equip the camera with a 20-in. lens so that larger scales can be obtained from higher altitudes. The 12-in. lens, generally used in mapping, will often require dangerously low altitudes to be flown so that the images will appear on the photograph in the desired size.

TYPE K-1 CAMERA

The Type K-1 camera was the first attempt at an aerial mapping camera by the United States Government in the late war, and, although now obsolete, it served, during the time of its existence, to show what was required in a camera for aerial purposes.

It was entirely automatic in action, the entire mechanism being driven by a wind motor into which was built a paddle wheel which connected with the shutter mechanism by a flexible shaft. By means of an adjustable intake the camera could be set into continuous automatic operation, or stopped at will. The wind to operate the paddle wheel was obtained by setting the wind motor directly in the wash of the propellor. By adjusting the intake the number of exposures made per minute was regulated.

Built into, and forming part of, the wind motor, was a Venturi tube which provided the necessary suction for holding the film in an even plane. The inner side of the latter was a perforated platen.

As the wind entered the motor it struck the blades in the paddle wheel, causing the wheel to revolve and operate the flexible shaft, which, in turn, operated the mechanism. The focal plane shutter, after releasing for an exposure, was rewound automatically, the film being carried along for the next operation at the same time.

The essential parts of this outfit were:

1. Camera.
2. Wind motor and shaft.
3. Venturi tube.
4. Vacuum back.

Description of Camera.—The camera was made up of two parts; the body and the interchangeable cones. The body was of aluminum, and the cones of sheet aluminum. Two cones were supplied with each camera, one being fitted with a 12-in. lens and the other with a 20-in. lens. With the 12-in. lens and cone, the camera weighed 33 lb. and measured 18 × 14 × 18 in.; and with the 20-in. cone and lens, it weighed 50 lb. and measured 18 × 14 × 32 in.

The camera body contained the focal plane, focal plane shutter, safety curtain, two rollers or spools for the film, two compartments for holding the film, automatic indenture pin, vacuum back, timing mechanism and exposure counter. A cone should fit very tightly to the camera body, otherwise it will vibrate and produce blur or distortion in the negatives. Cones should be handled carefully, for if they are bent out of shape it is practically impossible to make them fit snugly to the camera back. In the cones of both sizes the lens was in a barrel mount fixed to a cup that screwed in the end of the cone, there being enough threads to give a range of from two to three inches for focusing. After the lens had been screwed into the proper focus it was locked in that position by means of set screws.

Cycle of Operation.—The cycle of operation, entirely automatic, was as follows: After each exposure a safety curtain was instantly interposed between lens and film, the film was then wound into position for the next exposure. The focal plane shutter was reset and the safety curtain withdrawn just before the next exposure was made. The power was provided by a wind motor. Exposures were made upon a continuous roll of film $9\frac{1}{2}$ in. wide and 75 ft. long. The shutter was wound up on the roller while the safety curtain was closed. As the shutter was not self-capping it was necessary for the safety curtain to be closed all the time the shutter was being reset. After the aperture in the shutter had entirely crossed the focal plane and was on the roller the safety curtain began to open rapidly. When the safety curtain was fully open, the shutter tripped, making an exposure. Shortly afterward the indenture pin pushed upward and made a perforation at the edge of the film to indicate where the film should be cut in order to avoid mutilating exposures. The shutter immediately started to rewind, but before its aperture reached the focal plane the safety curtain was tripped and again protected the film

and allowed the shutter to be rewound and the aperture in it to pass across the film while it was being reset without exposing the film. During these operations the wind-up spool revolved constantly and was so timed that it made one complete revolution for each exposure.

The Shutter and Safety Curtain.—The shutter was of the focal plane type having a fixed aperture $\frac{3}{4}$ in. wide. In so far as the camera mechanism was concerned the length of exposure could be varied only by means of the tension. A further variation could be made, however, by use of filters. The tension on the shutter was increased by turning the key to the right until the tension number from one to twelve was registered in the aperture. Shutter speed was decreased by pressing forward on the escapement until the lower tension number required was registered in the aperture. The safety curtain was located at the bottom aperture of the camera body, just above the base of the cone.

Hand Operation of the Camera.—Six and one-sixth complete revolutions of the key made one complete cycle of operation. This provision for hand operation permitted inspection of the camera while on the ground and when disconnected from the power drive, or while in the air when it was desired to make a single exposure.

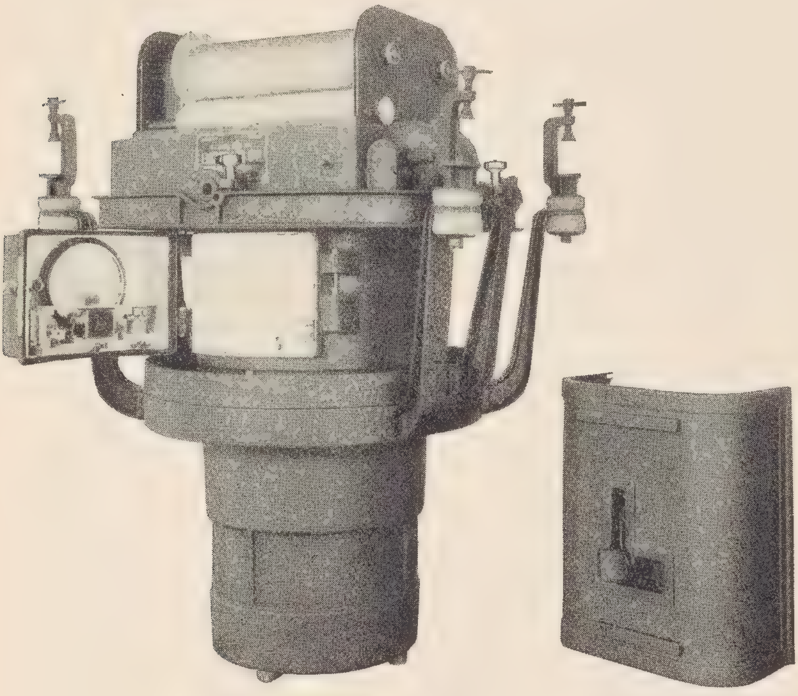
Timing Mechanism.—The timing mechanism which was encased and mounted on the side of the camera body consisted of two driving gears that transmitted the power from the power terminals to the timing gears through intermediate gears. The timing gears were three gears of seventy-four teeth each. The slow terminal had a speed of 600 revolutions for each cycle of operation of the camera. Fast terminal had a speed of 300 revolutions for each cycle of operation. If a flexible cable was attached to the fast terminal the camera was operated almost twice as fast as when attached to the slow terminal.

TYPE K-2 CAMERA

Description.—The K–2 camera was an adaptation of the K–1 for oblique aerial photography and was used in standard oblique suspension with 12-in. or 20-in. cone. The K–2 was exactly the same as the K–1 except that it had two curtain apertures instead of one. This model is also obsolete.

TYPE K-3 CAMERA

Principle of the Camera.—The K–3 camera is entirely automatic in its action. It is driven by an electric motor attached to the camera itself which is supplied by a storage battery. By means of a switch the camera may be set to continuous automatic operation or may be stopped at will. It is also possible at any time to operate



Courtesy Fairchild Aerial Camera Corporation
Fig. 18.—K-3 Camera

the camera by hand with the use of an attached crank. Manual operation can be done without disconnecting the electric motor drive. The electric power is regulated by an instrument known as the intervalometer which is a timing device for tripping the camera at regular, predetermined intervals. Only film is used in daylight loading rolls, each sufficient for 115 exposures. The essential parts of the outfit are:

1. Camera
2. Intervalometer
3. Storage Battery.

The Outfit.—The K–3 outfit, complete with accessories, comprises the following:

1 Field case.
1 Camera body complete with 12-in. cone and lens.
1 Electric motor, 12-volt.
2 Film magazines with empty spool for film and pressure plate.
1 Camera mount.
1 Intervalometer.
1 Storage battery, 12-volt with wiring.
2 Lamps, signal, 6-volt.

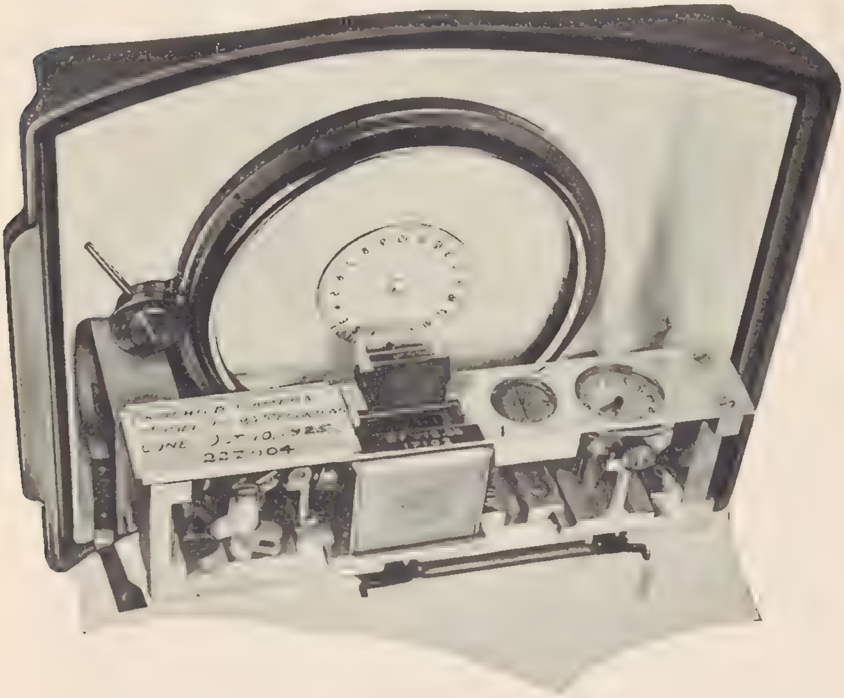
Description of Camera.—The camera is composed of three principal parts; the camera body, the shutter, and the film magazine.

The camera body contains the main drive mechanism, which is operated by a 12-volt electric motor. On the body are also mounted the necessary controls such as the knob for setting the shutter speed, the level and the levers for manually tripping and rewinding the camera. The manual operation levers are provided for emergency use only. Cones for either a 12-in. or a 20-in. lens are readily interchangeable on the same camera body. The lens is mounted in a between-the-lens shutter. The camera in the mount with one roll of film weighs 46 lb. The dimensions of the camera including the magazine but not including the mount are approximately $12 \times 18 \times 20$ in. The magazine when loaded weighs 14 lb.

The between-the-lens shutter is carried in the cone attached to the camera body. The retard for varying the speed of the shutter is a positive and reliable inertia device which is not affected by temperature or other varying conditions and eliminates the objections common to the plunger type of retard. The retard mechanism comes into action just as the shutter leaves reach the full open position, thereby allowing the shutter to open and close at high speed and increase the efficiency on the lower speeds. The shutter, mounted on a 12-in. cone, is graduated to give the following exposures: 1/50, 1/100, and 1/150 of a second. The shutter on the 20-in. cone, however, will give only 1/50 or 1/100 of a second. The film magazine takes the same size roll of film as that used in the K–1 and K–2 cameras, which is $9\frac{1}{2}$ in. wide and 75 ft. long. At the moment of exposure vibration in the K–3 camera is eliminated by stopping the motor. The film is pressed against an optically flat glass plate. The distortion of the picture due to photo-

graphing through this glass plate is compensated for when copying the mosaic. The glass is marked with lines which will photograph on the film and from these lines film shrinkage and location of the center of the negative can be determined. A film marker is provided so that exposures may be cut apart before developing.

The Intervalometer.—The intervalometer is a timing device for tripping the camera shutter at regular, predetermined intervals



Courtesy Fairchild Aerial Camera Corporation

FIG. 19.—RECORDING DEVICE MOUNTED ON SWINGING DOOR OF K-3 CAMERA, INCLUDING: ALTIMETER, WATCH, LEVEL, COUNTER, SPACE FOR DATA

which may be set according to the ground speed and altitude at which the airplane is flying. The interval range is from $7\frac{1}{2}$ to 90 seconds. Single exposures may be taken by pressing a button provided on the intervalometer. The instrument weighs $5\frac{3}{4}$ lb.

Removing Magazine from Camera.—Trip the shutter by means of the lever on the right side of the camera body by pulling the lever toward the operator. Then the film pressure plate in the magazine should be raised by turning the winding handle through

two complete turns which will allow the film to pass freely under the pressure plate when the magazine is being loaded. If there is used film in the magazine which is to be removed, the film follower should be wound into the film to protect it from the light by turning the knob in a clockwise direction. Facing the control side of the camera, pull the magazine lock slide on the right side of the magazine toward you and raise that end of the magazine, after which the whole magazine should be moved to the right and lifted from the camera.

Loading the Magazine.—Remove the magazine cover by turning the knobs on the side of the cover in opposite directions and lifting vertically. The knobs turn clockwise when facing them. Withdraw the light slide and remove the film pressure plate by pressing the thumb pieces together. Thoroughly clean both sides of the magazine glass with a soft linen cloth, after which the pressure plate and light slide should be replaced. Thread the paper film leader around the rollers under the pressure plate and onto the take-up spool. It is important that the film leader be given a true start, central with the flanges of the take-up spool. Otherwise, the side of the film that is crowding the flange will curl up and possibly tear, and the uniformity of the film spacing will be affected. Be sure that the light slide is in position and the magazine cover locked on before winding more than two turns of the film leader on the take-up spool. The cover will lock automatically when replaced on the magazine and pressed down.

Placing Magazine on Camera.—The magazines are interchangeable, but on account of the fact that accurate focus and alignment of the connection from the camera to the magazine drive must be maintained, they are a close fit in their recess on the camera body. For this reason the magazine recess and the bottom and edges of the magazine itself should always be wiped off before placing the magazine on the camera and it should never be forced into place. After placing the magazine on the camera left end first, be sure that by pushing the right slide toward the back of the camera, it is securely locked.

Setting the Film for Exposure.—Wind the film to the exposure position by turning the knob a sufficient number of turns in a clockwise direction or until the film indicator, seen through the window in the right end of the magazine, indicates zero. The film indicator shows approximately the number of exposures made and its

principal use is to determine the amount of unused film in the magazine. For an accurate count of exposures a reset counter is provided on the intervalometer. Before taking the pictures, the light slide must be removed and placed in the slot provided on the top of the magazine cover.

Preparing Shutter for Operation.—Before placing the magazine on the camera the open lens surfaces should be thoroughly cleaned with a soft linen cloth. Trip the shutter by means of the trip lever on the right side of the camera body by pulling it toward the operator. When tripping the shutter see that it opens and closes as it should and that it does not stop in the open position or partly open. If it should stop in the open position, the trip connecting rod should be pushed down and disconnected from the upper end, after which the shutter should be wound to close the leaves, the trip lever pulled once, the shutter rewound by turning the winding handle on the front of the camera body in a clockwise direction, and the trip rod reconnected. This should correct the trouble.

Setting the Shutter Speed.—The shutter speed may be set by means of a knob on the control side of the camera which may be depressed and turned until the pointer indicates the desired speed. The 12-in. shutter has three speeds, 1/50, 1/100 and 1/150 of a second. The 20-in. shutter has the two slower speeds only and will operate at 1/100 of a second at either of the two faster settings.

Changing Shutter and Cones.—Before changing the cones the shutter should be tripped to relieve the tension on the main spring. The cone with the shutter in place is removed from the camera by removing the nuts and bolts securing it. The desired cone is then attached to the camera body after carefully wiping off the surfaces that fit together so that any dirt, which may affect the shutter, will be removed. The upper part of the shutter wind connecting rod should be pressed down and connected to the camera drive. Wind the shutter by means of the winding lever after which the trip connecting rod should be connected.

Setting Intervalometer.—Before starting a set of pictures the exposure counter on the intervalometer should be reset to zero by turning the knob on it in a counter-clockwise direction. The upper center knob on the instrument is for winding the clock which should always be fully wound before each flight. The clock runs seven hours with each winding. When it is desired to start

making pictures at regular intervals the lower knob near the center of the intervalometer may be depressed and turned to any setting from $7\frac{1}{2}$ to 90 seconds, which will cause the shutter to be tripped regularly at that interval by a solenoid in the camera drive. The graduations on the indicator controlled by this knob represent seconds of interval between exposures.

Single Exposures.—Single exposures can be taken by pressing the button located to the right of the center of the intervalometer. Such exposures may also be made by pulling the lever on the right side of the camera.

Manual Operation.—The shutter is tripped, as described above, for a single exposure, after which the camera is rewound by means of the winding handle. This handle is unlocked by pulling on the knob, and rewound by turning five turns in a clockwise direction. The handle should always be left in the locked position.

Cycle of Operation.—In normal position the shutter is wound ready to be tripped. The film is pressed against an optically flat glass plate by the pressure plate and the film marker presses an indentation into the film to indicate the space between exposures. The shutter is then tripped by means of the manually operated trip lever or by the solenoid in the drive. After the shutter is tripped the motor circuit is closed by contacts in the camera drive, causing the motor to rewind the shutter and space the film ready for the next exposure.

Leveling the Camera.—A level is provided in a recess in the camera body which may be moved out to a convenient position and used in leveling the camera.

Determining the Film Shrinkage.—The magazine glass is marked with lines which will be photographed on the film for the purpose of determining the film shrinkage and locating the center of the negative. The size of the negative within these lines is $7 \times 9\frac{1}{8}$ in.

Lubrication.—Once a month two or three drops of Three-in-One or a good grade of clock oil should be injected into all oil vents. The grease cups on the motor should also be filled with a light grease. The gear housing cover should be removed from the end of the motor and the reduction gears lubricated with a light grease. The camera drive cover should also be removed and the gears greased, being sure not to use an excessive amount of grease.

Shutter.—The shutter should be removed from its holder and opened. A drop of lubricating oil should be put on each bearing.

The shutter leaves should be wiped off on both sides with an oiled cloth. All parts subject to severe shock due to high shutter speed should be carefully examined for wear and loosened parts. When the shutter has been operated ten thousand times the mainspring should be replaced to insure keeping the shutter speeds up to their ratings.

Camera Drive.—Remove the camera drive cover, examine the reduction gears for wear and see that the revolution pawl and ratchet are in good condition. Clean the motor circuit contact points with fine sandpaper or a fine file, being very careful not to bend them out of adjustment. Two or three drops of lubricating oil should be used in these points.

Intervalometer.—The intervalometer cover should be removed and the intervalometer lubricated with two drops of oil. Carefully examine the ratchets and pawl to see that they are in good condition. Clean contact points in clock movement with a fine file or fine sandpaper being careful not to bend them out of adjustment. The ends of the spring plungers and the surfaces with which they make contact should also be cleaned.

Replacing Camera Drive.—The camera drive is attached to the camera body by four screws, which makes it a very simple matter to replace this unit. Before replacing the drive the connecting rod to the motor should be removed by pressing it toward the motor end which has a compression spring. Before attaching a new drive in place see that the terminals under the solenoid, which make contact with the spring connections in the camera body, are perfectly clean and will make a good firm electrical contact.

Replacing Motor.—To replace the motor, the connecting rod to the drive should first be removed and the motor leads disconnected. The motor is attached by two bolts.

Replacing Motor Brushes.—Remove the four brushes after taking off the brush holder covers. The new brushes should be placed in the holders so that the concave end of the brush conforms to the commutator face. The motor should then be run without any load, or not over four volts, until the end of the brush is a perfect fit on the commutator.

Replacing Shutter.—Before removing a shutter from its holder the connecting rods should always be disconnected from the camera drive by pressing the upper end of the rods down toward the shutter. The shutter is held in its holder by means of three screws.

Whenever a shutter is changed in a cone the retard plunger, which belongs to that shutter, should also be replaced as these plungers vary in length in conformity with the shutter focus. Be sure that each retard plunger is kept with the shutter for which it is intended. The shutter serial number which is stamped on the outer rim of the shutter case is also stamped on the retard plunger for identification. The focusing posts are also cut to the proper length to bring the shutter in focus and should never be changed or removed from the shutter for which they were made.

Replacing Connecting Rods.—The connecting rods are held in their sockets on the shutter by means of spring rings which may be removed by means of a sharp-pointed tool.

Replacing a Shutter Leaf Housing.—Remove the cotter and washer from the stud in the shutter stop cam. The leaf housings are held in place by only four screws.

Replacing Main Springs.—To replace a main spring remove the main spring chamber from the rear of the shutter after disconnecting the winding connecting rod. This spring should be replaced every 10,000 operations to insure keeping the shutter speeds up to their ratings.

Replacing Retard.—To remove a retard, drive the taper pin from the retard lever on the rear of the shutter. When the new retard is put in the shutter case be sure that the taper pin is driven home.

Replacing Stop Cam.—After removing the spring chamber from the rear of the shutter, drive the taper pin from the spring cup. This will allow the stop cam and shaft to be replaced. See that the taper pin is driven tight before attaching the spring chamber again.

Replacing Magazine Drive.—To remove a magazine drive, it is first necessary to disconnect the pressure plate shaft by removing the screw and then to remove the film roller at the back of the magazine by loosening the screw. The drive is held in position by only four screws.

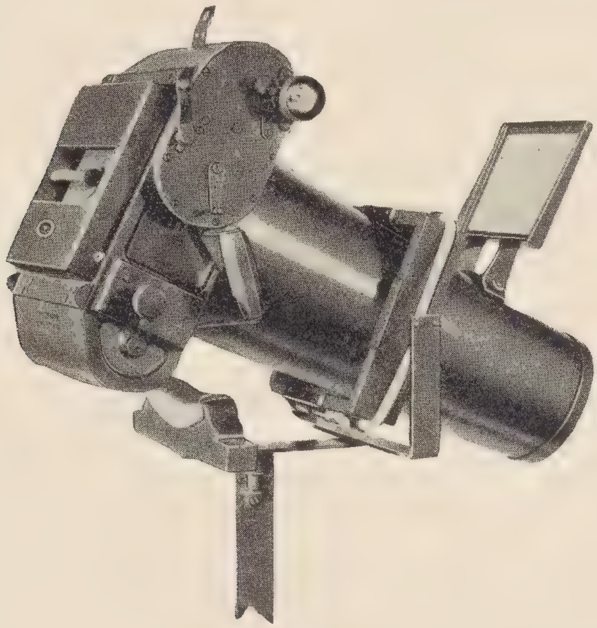
Replacing Magazine Glass.—Remove the pressure plate from the magazine, after which the glass retaining strips may be easily removed. In placing the new glass be sure that the new strip is toward the back of the magazine and nearest to the magazine drive.

TYPE K-4 CAMERA

The K–4 camera is designed for taking vertical aerial photographs and is the same as the K–3 except that it is fitted with a 20-in. cone and lens. The body parts of these two cameras are identical and the 20-in. and 12-in. cones are interchangeable.

TYPE K–5 CAMERA

This is a hand-operated camera, combining the chief characteristics of the K–1 and the K–2 models, except for the fact



Courtesy Folmer Graflex Corporation

FIG. 20.—K-5 CAMERA

that it is not automatic. By winding the crank a few turns, the film is drawn into position for exposure and the shutter set. The shutter is tripped by pressing on the release. The length of exposure can be varied from 1/60 to 1/280 of a second, giving a wide range of length of exposure to meet various conditions of light and haze. The camera body is so constructed that it can be used with either a 12-in. or a 20-in. cone. The lenses used are anastig-

mat *f*. 4.5. The K–5 camera can be used for both obliques and verticals.

Loading the Camera.—Remove the vacuum back by pushing the two sliding locking bars to the right, assuming the Venturi tube is on the left, and lift up the vacuum back. Swing down the doors of the film compartments, draw out the *S*–1 spool center and, by turning, set it in the extended position. Hold out the spool center *R*–1 and before breaking the paper seal on the spool of film press the flanges of the spool against the tension springs at the ends of the film compartment and push the roll in as far as it will go. Release the spool centers *R*–1 and *S*–1 and turn the roll of film until the spool centers snap into position in the ends of the film spool. The roll of film must be placed in the film compartment so that the film will unwind from the top of the spool and the paper seal should not be broken until the spool is in position. See that the brush encircles the film roll. Pull out the spool center *S* and by turning, set in the extended position. Hold out center *R* and press an empty winding spool against the two springs and into the film compartment as far as it will go. Release the two centers *R* and *S* and rotate the spool until the centers snap into engagement with the ends of the spool.

Attaching the Film.—Break the paper seal on the roll of film and draw the paper across the recording or focal plane. Make a small fold in the end of the paper and slip it under the brass clip on the winding spool so that the end of the clip will hook into the fold. If the brass clip is not in position, turn the winding key a few revolutions in order to bring the clip into the most convenient position for hooking the paper. Then set the exposure tally at 0 and turn the key until the shutter trips about two or three times, feeling the paper to see that it is running straight and with even tension and not building up at one end.

Attaching the Vacuum Back.—Swing up the doors of the film compartments and place the vacuum back in position, with the locking bars extended to the right, assuming the Venturi tube is on the left. Then, while pressing inward on the two compartment doors, engage the holes in the locking bars with the studs on the doors and press the locking bars to the left as far as they will go, thus securely locking the doors and the vacuum back in position. The back should be carefully fitted in. If it has received a blow or for some other reason is too low, and therefore too near the guide

rollers, it may cause abrasion marks on the film curtain in the form of fine parallel scratches.

Setting the Film for Exposure.—After the vacuum back has been attached, run the motor or turn the key until the exposure tally shows "13." The amount of black paper regularly furnished with the K–5 film is of such length that it requires thirteen trips of the shutter before the film comes over the exposure opening. The fourteenth trip, counting from the time the paper is first threaded, will, therefore, be the first exposure. Do not open the camera back after the paper has been wound up, as the film is unprotected and will be light-struck if the back is removed except in a dark room. The spool center R–1 will revolve until the film and paper are completely unwound from the spool and then it will stop. After the roll of film has been exposed the paper on the inner end of the roll is wound over the exposed film on the spool and the exposed roll may then be removed.

The Vacuum Back.—The top of the vacuum back is reinforced by a wooden frame in which two spirit levels are set at right angles to each other. There is also an aperture in this wooden frame through which the rubber hose is passed, which connects the suction head with the Venturi tube. The inner side of the vacuum back is a graphited, cloth-covered, aluminum platen containing many small perforations which enter the hollow chamber to which the hose from the Venturi tube is attached. By means of the rush of air through the Venturi tube a partial vacuum is created in this chamber which holds the film against the level platen back at all times. In order to prevent excessive suction on the film the L-shaped connection on the camera top is provided with a release valve at one end. This valve automatically opens when the suction increases beyond the point required to hold the film flat and free from vibration. During the flight this valve should always be partly open. The platen across which the film is drawn should be kept covered with powdered graphite to overcome static effects in the film caused by undue friction between the film and the vacuum back. The powdered graphite should be applied if possible after the exposure of each roll of film. Static electricity generated as the film is drawn from the roll is collected by the brush partially encircling and in contact with the roll of film.

Examination of Camera.—Every camera, after flying, should be looked over very carefully, particularly to see whether the safety

curtain and shutter curtain are working properly. The cone should be removed and the lens cleaned in readiness for another trip. It will always be found that a certain amount of dust has collected on the back of the lens as well as inside the cone and, after the exposure of two rolls of film, this amount of dust becomes great enough to cut down appreciably the light passing through the lens. To remove this dust, a small camel's hair brush seems to be best adapted for the purpose. It is always best to let the tension of the shutter down to No. 1.

TYPE K–6 CAMERA

The K–6 camera is used for taking oblique photographs. It is equipped with a 20-in. focal length lens of focus variable from 100 to 700 ft. A sunshade is provided and the shutter is of the focal plane type. It is manually operated and a trigger is provided with which to make the exposure. This trigger is similar in construction to that of a revolver.

TYPE K–7 CAMERA

This camera has a 36-in. focal length lens and is intended for high altitude work. It takes a picture 9 × 18 in. instead of the usual 7 × 9-in. size.

CONSTRUCTION AND OPERATION OF TYPE T-1 CAMERA

In constructing the T–1 camera the design was to produce an instrument which would cover in one exposure as large a ground area as possible. This was accomplished by joining, fan-like, three V-shaped cameras, the center one taking a vertical picture and the end ones taking oblique views which extend the vertical view on both sides. The three cameras are so joined that their lenses are as near as possible at one point and their focal planes are separated only by thin partitions. Roll film passes across these three focal planes, and the automatic diaphragm shutters on the lenses are so connected that they are released simultaneously and an exposure made in all three cameras. In a transforming camera, prints are made from the oblique-view negatives, which are the equivalent of the vertical view, so that the final result is a vertical view in three parts, which covers a wide strip on the ground.

Description of the Camera.—The camera proper consists of a base divided by partitions into three chambers, a separate magazine containing a roll of film, and the mechanism required to wind the film across the focal planes. The magazine is clamped tightly to the base when the camera is loaded for use. Each of the three compartments in the base is fitted with a lens and focal plane of thin glass. The lenses are mounted in automatic, between-the-lens shutters which are released together by a three-pronged plunger. The speed of the lenses is *f*. 4.5. The focal length of the center lens is about $6\frac{1}{2}$ in. and the focal lengths of the side lenses are about $7\frac{1}{4}$ in. The center focal plane is equipped with two level-bubble vials which are aligned at right angles to each other. These stand practically in the focal plane and their images are registered

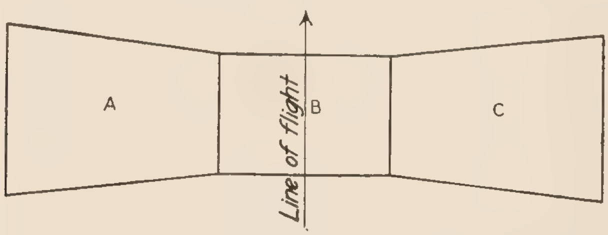


FIG. 21.—AREA COVERED BY A TRI-LENS PHOTOGRAPH

on all negatives made in the center chamber. The base is so constructed that the side focal planes form dihedral angles of exactly 35 deg. with the center focal plane. The lenses of the side chambers are carefully matched in focal length. The base is also equipped with a punch which automatically punches the film at the middle point between sets of negatives at each exposure. This film punch is actuated by the release plunger. Negatives from all three of the chambers are $5\frac{1}{2} \times 6$ in. in size. The magazine takes single rolls of film 6 in. wide and 380 ft. long. It is equipped with two film spool seats, a crank to wind the film, two level-bubble vials set on top in the form of a "T," a dial which indicates the proper length of film to wind off for each exposure, a handle to lift the camera and three cloth-faced pressure plates which hold the film against the focal plane plates. Rollers are placed at all points where the film has to turn when being drawn along its path. The camera is mounted vertically in the airplane as will be explained later. The T-1 camera is entirely hand-operated.

The release mechanism consists of a lever, flexible cable, a counter to register the number of exposures and a stop-watch for timing the exposure intervals. The release mechanism is mounted in the cockpit on the right side of the observer where its lever may be easily reached. The cable release forms the connection between the release mechanism and the camera. The combined scope of the three views made in the camera across the line of flight is three times its elevation above the ground. The scope in the direction of flight is nearly five-sixths of the altitude. The making, in the transforming camera from the oblique negatives, of prints which are in the same plane as those obtained by contact printing from the center negative has been explained in Chapter I.

Loading the T–1 *Camera.*—The panchromatic film which is supplied for use with the T–1 camera is sensitive to all light. It must, therefore, be handled with extreme care to prevent fogging. Never open the container of the film nor load the camera except in a dark room equipped with proper safelight, such as the Series 3, Wrattan and Wainwright. Even this light should be used only when absolutely necessary as it is best to work in complete darkness as far as possible. *A red light is not safe.* Also, remove the film from the camera in the darkroom and keep it securely protected from light until developed. Loading or unloading the camera in daylight will result in fogging the edges of film which will destroy the full value of negatives.

To load the camera, remove the circular window and the center pressure plate from the magazine. Thread a strip of gummed tape 30 in. long from the empty spool (which is in place at the top of the magazine) to a point outside the first end roller. Slip the end of the tape through the spool slit, moisten about 1 in. from its end and stick to form a loop which can slide sidewise in the slit. Do not stick the tape to the core of the spool for doing so may prevent the leader paper and the film from winding up properly on the spool. Pass the tape backward along the path of the film (see white line on outside of magazine) until its free end hangs outside the magazine. This can be done with light. Now darken the room and take the roll of film from its container. Break the seal, pull up about 2 ft. of the leader paper and thread it backward through the pressure plate aperture with the rolled-in surface turned out. Draw it across to meet the end of the tape and gum them together.

Avoid twisting the tape and be sure to have the tape fast to the paper all along the parts in contact. The tape should be attached at the middle of the paper end. Now adjust the tape loop to the middle of the core of the empty spool. Insert the spool of film in its seat. Note that the pins of the seat are beveled. Screw one of them toward the spool so that it will project a little, then shift the spool until its recess drops over the pin. Both pins can now be readily screwed in to hold the spool. When thus inserting a spool of film care must be taken to avoid injuring the leader paper. See that there is just the right amount of slack before inserting the spool.

The spool of film in place, draw off about 1 ft. of the leader paper and hold it lightly with one hand, cranking slowly with the other to wind the empty spool. Do not pull the tape end of the paper but allow it to wind toward the empty spool without slack but without tension. After reaching the spool it will then go on properly. If pulled, the paper is liable to roll against the flanges of the spool and be crimped. When the paper reaches the empty spool, feel through the circular window to make sure that it is winding on properly. As soon as a proper start of the paper on the spool is made, wind the paper until all slack is taken up, then replace the window and the center pressure plate. Take hold of the magazine, and bring it gently down over the base, setting it into place by feeling the outer edges of the base. A little practice is required to do this readily. Take particular care in this step not to jam one of the glass focal plane plates.

Having the magazine in place on the base, wind the crank a little to test the freedom of movement of the paper. If it fails to move freely the paper has not been placed properly between the guides at the sides of the focal planes. In this case it will be necessary to lift the magazine from the base and set it on again. Having obtained free movement of the paper, screw in the four clamping screws which hold the magazine on the base. Turn on the light and wind the crank until the end of the film passes the focal plane. The leader paper is about 8 in. long, so three or four revolutions of the dial are required to wind up the paper. It is possible to tell when the film reaches the first focal plane since there will then be a slight increase in the push required to wind the crank. On feeling this increase in tension, wind one more full

turn of the dial. Always wind the film across the focal planes before leaving the darkroom because any roughness at the joint between the paper and film may cause the paper to tear loose. With the end of the film past the focal planes, there is no danger of winding failure.

CARE OF CAMERA AND ACCESSORIES

Cautions in Handling the Camera.—The camera is of construction strong enough to withstand all vibrations and shocks incident to shipping, proper handling, and actual use. It must be carefully handled so as to avoid injury to the more delicate parts, such as the lenses, the shutters, the level bubble vials and the focal plane plates. No part of the camera should be allowed to have its position changed. Whenever it becomes necessary to adjust or exchange a part, the new part must be set accurately in position.

Lenses.—The lenses must be kept clean and securely in place. Use a camel's hair brush to remove dust. To remove grease dampen the surfaces of the lenses, then rub gently with a soft cotton or linen cloth.

Shutters.—An extra shutter is included for each lens to provide against the contingency of shutter derangement. These have been fitted to the camera along with the shutters in place and are marked, each for its particular lens (stamped metal on face of shutter). When a shutter becomes deranged, it is essential that its proper duplicate be used in replacing it. The shutter, when out of order, should be promptly repaired and placed in its niche in the case. Always test the timing of the shutters before loading the camera. The shutters must be so timed that they all click with one sound when released by a slow push on the plunger. To test the timing of the shutters, push the plunger in as slowly as possible with a pencil and note the sound. Timing adjustments are made by changing the flat-headed screws which make contact with the short stems of the shutters.

Level Bubbles.—Test the level bubbles occasionally to see that those in the focal plane accord with those on top of the magazine. The bubbles of both sets of vials should stand at centers when the center focal plane is horizontal. Do not allow the sun to shine on the level bubbles during warm or hot weather nor allow the camera

to stand in an excessively heated place, because the liquid of the level bubble vials expands enough to break the vials at about 110 deg. F. Each division of the graduations on the level bubbles indicate 10 minutes of arc. The bubbles have a range of 3 deg. each side of the center.

Focal Planes.—Before loading the camera examine the focal planes and all other surfaces where the film bears, in order to make certain that there are no burrs to cause excessive friction or to score the film when winding. The film should slide freely when being wound. To assure free passage of the film, stops are provided on the sides of the focal planes to prevent the pressure plates from pressing the film tight against the focal plane plates. The film is 7/1,000 of an inch thick. The distance between the focal plane plates and the pressure plates should be 17/1,000 to 20/1,000 of an inch to assure free passage of the film. Run the tips of the fingers all along the flat surfaces of the focal planes and if burrs are found rub them off carefully with the crocus cloth. Be careful not to score the glass plates when using the crocus cloth. Clean all dust and grit from the camera before loading. The pressure plates which hold the film in contact with the focal planes must remain flat. Their cloth surfaces have powdered graphite rubbed on them to prevent static electricity from marking the film during operation of the camera. See that loose particles of the graphite are removed. They will work down to the focal planes and cause specks on negatives if not removed. Especial care must be given to the thin glass plates to prevent them from being broken or scratched. When it becomes necessary to replace one, be sure to use the proper duplicate as indicated by the number and letter of the stencil. When inserting a focal plane plate it is necessary to have the lines on it match the lines on the metal frame which supports it. Most of the glass plates will be found to have a little play in the recess. The screws which hold the plate in place can be run in so as to catch the plate exactly in its proper position. Be very careful when driving in the screws not to crack the plate. Do not force them against the plate.

Color Screens.—Each lens carries a disk of K–3 color screen between its front element and the leaves of the shutter. When changing color screens be careful not to touch the gelatine with the fingers except at its edges. Extra pieces of both K–3 and Minus Blue color screens are provided in the case.

Punch.—A film punch is provided, which punches the roll of film between each set of three exposures. This is provided for the purpose of indicating, in the darkroom, the proper place to cut the film if more than one development is necessary. Care should be exercised to assure the proper functioning of this punch, as the film may be torn if the punch remains in the punching position when the film is being wound.

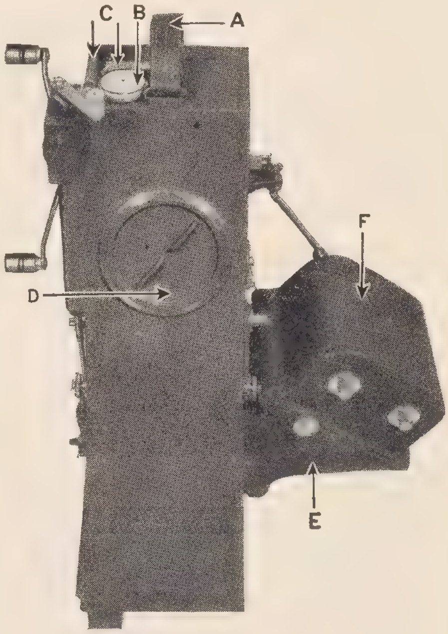
Dial.—The dial is connected with the film at the winding spool by means of gears, a shaft with universal joint and a sharp-toothed wheel, which bears against the film near its edge. One complete revolution of the dial is made when enough film for an exposure is wound off.

INSTALLATION AND OPERATION

Installation of the Camera.—Open the rectangular wooden frame and fasten it on the camera trunnions. Remove the large wooden inset which closes the hole in the floor of the cockpit. Mount the circular arc metal support arms (with sliding trunnions attached) on the brackets provided in the cockpit by means of the cushioned clamps. Standing in the cockpit, have the camera passed from the ground, and lift it into position, the crank face aft. Tilt it slightly to one side and engage one of the trunnions with a cone of the rectangular frame. Turn the vise bar until the screw takes hold. Press the opposite circular arc bar outward until its trunnion engages the other cone of the frame. Screw in both vise bars until the camera stands rigidly in any position. The plate carrying the release mechanism has slotted metal bars provided in the cockpit to which it may be anchored. In the first installation it is necessary to spot and drill holes in two upright wooden bars to attach the metal bars. Wing-headed bolts are provided to fasten the plate to the bars. These are anchored in the metal bars. The release mechanism in place, unscrew the outer part of the bracket which holds the head of the release cable. Screw the release cable to the camera stem. Insert the head of the cable and screw on the bracket piece. The head of the release cable should not be clamped too tight for it may be thereby so pinched as to prevent its free operation. Now install the view-finder. With someone inside the cockpit to throw the lever, get under the airplane and observe the shutters while the release mechanism is

being operated. See that all open and close properly. Examine the settings of the shutters to see that they are right.

Use and Operation of the Camera.—T-1 cameras are used in aircraft to obtain overlapping photographs in series for making maps and military reconnaissances. All U. S. Army Air Corps observation airplanes are fitted to accommodate the multiple lens cameras as well as single lens cameras. Protection must be provided for the lenses during the take-off when the ground is muddy. The lenses should also be protected when sand is flying about. Protection can be provided either by tying a piece of cloth over the lens face of the camera to be removed after getting off, or by covering the hole in the floor with a piece of cardboard which can be held in place with the feet. For landing and for taking off when the ground is dry, it will be sufficient to turn the camera into its extreme oblique position with the lenses forward. Once under way, clear off the cloth (or remove the cardboard) and test the release mechanism to see that all parts are working. This done, wind the crank to bring fresh film into position. Test the wing screws which clamp the frame to the trunnions to obtain the proper stiffness at joints to permit adjusting the camera and to hold it in position.



Courtesy Fairchild Aerial Camera Corporation

Fig. 22.—T-2 Camera—Side View

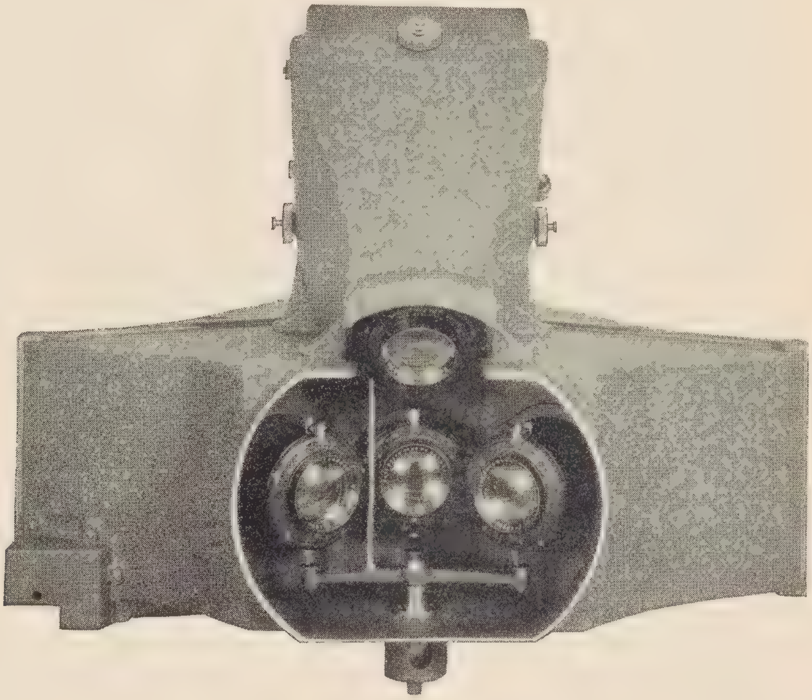
A, Strap handle. *B*, Interval stop-watch. *C*, Levels. *D*, Film-loading aperture. *E*, Fourth chamber. *F*, Individual film magazine for chamber 4.

FOUR-CHAMBERED CAMERA (T-2)

In constructing the four-chambered camera another chamber was added to the tri-lens camera. This additional wing section

acts somewhat as a rudder in orienting photographs. The third wing also gives an oblique view of every part of the terrain photographed. This offers a means of determining elevations from the photographs or from the composite photograph.

The lateral scope (across the direction of flight) is three times the altitude of the camera, and its longitudinal scope (in the direction



Courtesy Fairchild Aerial Camera Corporation

FIG. 23.—T-2 CAMERA—BOTTOM VIEW

Showing four lenses and shutters with their tripping mechanism.

of flight) is $1\frac{3}{4}$ times the height of the camera. An example of this would be a picture taken from 15,000 ft., the lateral scope of which would be nine miles (same as the tri-lens) and the longitudinal scope nearly five miles. In contrast to this, the longitudinal scope of the tri-lens from the same altitude is only about one mile.

Courtesy Fairchild Aerial Camera Corporation

Fig. 24.—Manner in which the Different Chambers of the T-2 Cover the Area being Photographed

The ground area covered by each chamber being outlined.

T–3 CAMERA

The T–3 camera is similar in construction to the T–2, only in place of having four chambers a fifth has been added. The large area included in one exposure makes it possible to extend the primary control points, securing the secondary control that can be rapidly and accurately carried forward.

Courtesy Fairchild Aerial Camera Corporation

Fig. 25.—Type of Picture Obtained by Four-chamber Camera (One Exposure)

AERIAL CAMERA F-8 (ENGLISH)

This camera is principally used for mapping. It may be controlled automatically or by hand. When using the electric controls the exposures are made automatically in regular succession at a predetermined time interval. A push-button control enables the photographer to make single exposures between the automatic ones. When not using the automatic control the camera is operated by hand. The film is changed and the camera set either by electric motor or by a windmill placed in the slip-stream. The exposure is controlled by means of an adjustable lens aperture, the slit and tension of the shutter remaining fixed. The

width of the shutter slit is sufficiently small to prevent the bad effects growing out of vibration and it is large enough for exposures on dull days with the lens aperture open to its widest extent.

The camera consists of:

Lens cone	Windmill
Film magazine	Flexible drive
Camera body	12-volt battery
Gear box	Volt meter
Instrument box	Pilot's indicator lamp
Focal plane shutter	Motor unit
Fuse box	Friction tester
Electrical control	

Three lens cones are provided. These accommodate lenses of the following focal lengths:

No. 1 cone, 7-in. focal length
No. 2 cone, 10-, 12-, and 14-in. focal length
No. 3 cone, 20-in. focal length

The cone is attached to the camera body by bayonet slots and is locked in position by a rachet and catch. The lens is provided with an iris diaphragm which is operated by setting with a knob.

The magazine consists of two spools carrying the exposed and unexposed film.

A measuring device with sharp pins is provided. This device makes approximately two revolutions to wind over the required amount of film.

There is a counter which indicates the number of exposures. The counter can be set back to zero.

The indicator reveals when the film is changing or remaining stationary.

The protective cover is used to keep the film aperture from damage and to fold around the magazine in position.

The pressure pad is to hold the film in close contact with the glass plate in the camera body during exposure.

The camera body carries the cone, gear box, focal plane shutter, and magazine.

A glass plate forms the focal register upon which are engraved the principal point and enlargement marks. The top surface of the casting surrounding the glass plate is in the plane of the focal register.

The gear box is an aluminum casting containing the mechanism which changes the film, sets the shutter, and controls the counters. It is hinged to the body and locked in position by a thumb screw. It is easily detached. Its function can be divided into two headings, mechanical and electrical. A release block is provided on the outside of the casting to which a Bowden cable can be readily attached and locked. The depression of the lever performs three functions: first, it makes electrical contact, lighting the lamps in the instrument box; secondly, it releases the shutter; thirdly, it engages the train of gears. Five turns in a clockwise direction of the changing handle complete the cycle of operations, which involves winding the film, setting the shutter, and moving the counters and indicator. In addition to the hand-operation, a mechanical drive is provided through a worm-wheel whereby the cycle of operations may be performed either by the motor or the windmill. The changing handle may be turned in either direction with or without the automatic drive running. The first movement of the lever, when making an exposure by the mechanical control, closes the instrument box lamp circuit.

The instrument box is located in the camera body. It contains five instruments, the readings of which are registered on each exposure, the images being produced on the film by lenses fitted in the top of the box. These five instruments are:

Height aneroid.
Serial number of the picture.
Angle of tilt indicator.
A tablet engraved with the camera number is provided with a space in which can be written the focal length of the lens, etc.
A thirty-hour watch.

The focal plane shutter contained in a casting consists of one main blind and a capping blind. The main blind has a fixed slit 7/8 in. wide and a tension to give exposure of 1/90 of a second. The tension should be one-half turn from zero with the blind at rest. The capping blind tension requires six turns from zero with the blind at rest. The removal of a pin and washer enables the pinion shafts to be pulled out and the complete roller removed. The tension shafts are provided with a quarter-turn adjustment and are locked in position with two screws.

The electric control unit is self-contained, consisting of an electrically maintained clock movement which automatically makes exposures at any predetermined time interval between 10 and 60 seconds. The adjustment of the time-interval setting knob is made visible by the red hand on the calibrated dial. This knob sets the time at which it is desired to make successive exposures. The counter dial gives visible indications of the number of exposures and can be set back to zero by a knob. The set indicator, after each exposure is made, moves in such a manner that the word "set" shifts out of sight and remains so while the mechanism completes the operations of changing the film and resetting the shutter. When the word "set" reappears the pilot's indicator lamp goes on. This gives the pilot five seconds warning before the next exposure.

The Type-8 camera mounting is so designed as to enable the camera to be leveled in two directions. Vibration is reduced by felt packing in the casting. This mounting can be rotated about the optical axis 80 deg. (40 deg. each way).

FOCUSING AERIAL CAMERAS

A camera is said to be in focus when the image formed by the lens coincides with the emulsion side of the plate or film. The distance behind the lens at which the image is formed depends on the distance of the object except when that object is a great distance away from the camera. Then the object is said to be at infinity. Aerial cameras have a fixed focus as the objects taken by them are beyond infinity. For all objects nearer than infinity (usually within 100 ft.) the distance from the lens to the plate when the camera is in focus will be greater than the focal length of the lens. The effect of taking a picture with a plate out of focus is to render the images of the points composing the objects as small overlapping circles, which will result in a blur. Although the aerial camera usually has a fixed focus, the lens is screwed into the cone of the camera and often slips slightly, throwing the camera out of focus. Aerial cameras are focused at infinity.

Focusing from Test Exposures.—Focusing by test exposures, while giving very accurate results, is the slowest method. In order to approximate the focus as closely as possible before going into the air, the lens should be focused on a sheet of ground-glass placed in the same plane that the plate or film will occupy when the camera

is used. Some prominent object, such as a large building at least a mile away, should then be selected and sighted on, and the lens adjusted until a sharp image is registered on the ground-glass.

The camera is ready then to be taken in the air and test exposures made. This is done by first taking a picture with the lens in the same position as when approximately focused on the ground-glass. The lens is then turned to the right a quarter turn and another picture is taken. This procedure is continued, that is, a picture is taken at every quarter turn until a full turn has been made. The lens is then turned back a full turn to its original position, and then turned to the left a quarter turn. This process is continued, making exposures every quarter turn until a full turn has been made. The lens is then returned to its original position. This roll of film should then be developed and printed and comparisons made between the pictures.

Focusing by a Ground-Glass.—It is possible, but not as accurate, to make a complete focus by means of a ground-glass. The ground-glass should be placed in the camera in the same position as in the last paragraph. The camera may then be focused from the air or on some distant object. A black focusing cloth should be used to keep out the undesirable rays of light.

Focusing by Parallax.—Parallax is the term used to denote the relative movement which takes place between two objects at different distances from the eye as the eye is moved from one position to the other. In order to observe the motion it is necessary to use a piece of clear glass instead of a ground-glass. This glass should be ruled either with a number of parallel lines or with cross-lines so that the relative motion can be detected. It is more convenient if the focusing glass has a portion of it ground, since in this way it is possible to focus approximately on the ground-glass portion before focusing by parallax. In order to detect a small amount of motion a small magnifying glass should be used. This glass should be free from all defects. The essentials of the methods are as follows:

1. Bring the subject roughly into focus on the ground part of the glass.
2. Select some small piece of detail of the object that is in the clear portion of the glass and that shows near the lines marked on the glass.
3. Note whether this part of the image appears to move or

whether it remains relative to the marks on the glass when the eye is moved through a lateral distance.

4. If the image moves with the eye, the glass is behind focus. If the image moves from the eye, the glass is in front of focus. If there is no visible movement the focus is as exact as possible.

Focusing by Collimator.—The collimator, an instrument for the production of a parallel-sided pencil of light rays, consists of a metal tube about 40 in. in length and 4 in. in diameter. At one end of this tube is a very finely ground glass upon which has been drawn a lens testing chart. At the other end of the tube a compensating lens is mounted. The instrument is used as follows:

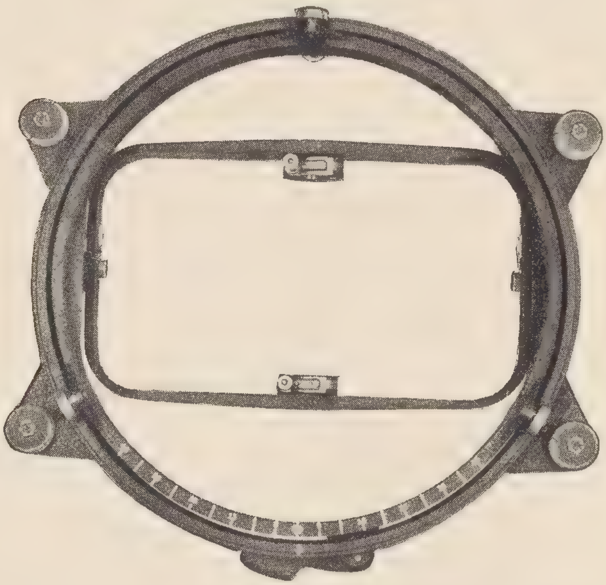
A reflector is placed at a convenient distance from the source of light at such an angle that the maximum amount of light is reflected through the the chart onto the ground-glass. The camera is placed so that the principal axis of its lens is in line with the principal axis of the collimator. All stray light must be excluded from the junction of the collimator and the lens and the whole system rigidly mounted. A sheet of finely ground glass is inserted in the place normally occupied by the photographic plate or film. When making the adjustment a very bright image of the chart is thrown onto the ground-glass, and the collimator insures that all rays of light that enter the lens shall be parallel to its principal axis. If the image is carefully focused on the screen the correct relative position of the lens and ground-glass which has taken the place of the plate or film will have been determined.

CAMERA MOUNTS

The problem of installation of aerial cameras presents more difficulties with the increased weight, size and focal length of the aerial cameras and the velocity of the airplane. The purpose of the suspension system is to prevent the camera from being affected by the vibration of the airplane, caused by the motor, or by the reaction of the parts of the plane to the strain incident to flight, and to prevent the slow movements of the plane from being transmitted to the camera. As this can be accomplished only by a gyroscopic suspension, all possible provision should be made to prevent vibration from affecting the camera. This can be partially accomplished by installing the camera in a point of the plane

where vibration is at a minimum and by connecting the camera to the suspension by means of substances capable of absorbing vibration.

With regard to the location of the camera in the plane it is not always possible to install the camera at a point where the vibration is at minimum, but if a choice of location is given, the point of least vibration should be considered. If all points of attachment to the suspension were subjected to identical and synchronized vibratory movement the camera would only be subjected to small



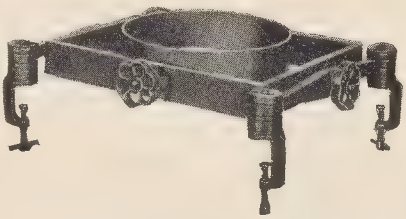
Courtesy Fairchild Aerial Camera Corporation

Fig. 26.—Universal Mount

translating movements, but as the different points of the suspension undergo vibrations of different amplitude and phase, the camera is subjected to rotary movements which will cause blurring of the photograph. Therefore these vibrations must be absorbed so that the camera will be affected as little as possible. Elastic material, such as steel, will produce oscillary movements that will last for some time before being damped and may take a serious amplitude on account of successive impulses. Non-elastic material, such as cork, felt, and sponge rubber, have proven the most suitable materials, since besides absorbing vibration they readily

damp the oscillations. Provision should be made so that the direction of the total reaction of the suspension passes as closely as possible to the center of gravity of the camera. Only by experimentation is it possible to ascertain the quality of a given system of suspension for each type of camera and aircraft.

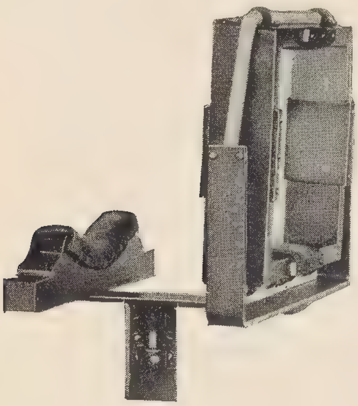
Test for Vibration.—To make a test for vibration a night flight should be made over a field where there is only one source of illumination. The shutter should be left open during the flight over the light. The point of light will trace on the film a line which is more or less irregular according to the vibrations of the camera. The camera could be shifted to all available locations in the plane until the point is found where the least vibration exists. Vibration is an element of no small importance and its correction or reduction should not be sacrificed for considerations of space and weight.



Courtesy Folmer Graflex Corporation

Fig. 27.—Vertical Mount for K-5 Camera

The K-1 and K-5 Mount.—The suspension used for the K-1 and K-5 cameras is a gimbal mount. This mount consists essentially of two arms or supports fitted with winged screws which allow it to be fastened to horizontal supports in the ship. On the tops of these fittings are spools of sponge rubber which support the weight of the camera and the mount and take up the vibration. At the center of the arms, fastened by winged bolts which allow it to be tightened in any position, is a framework suspended so as to hang always perpendicularly, due to the fact that its center of gravity is below the point of suspension. This allows the camera to be moved backward and forward and allows the observer to correct the level of the camera if the pilot has the ship off-level



Courtesy Folmer Graflex Corporation

Fig. 28.—Oblique Mount for K-5 Camera

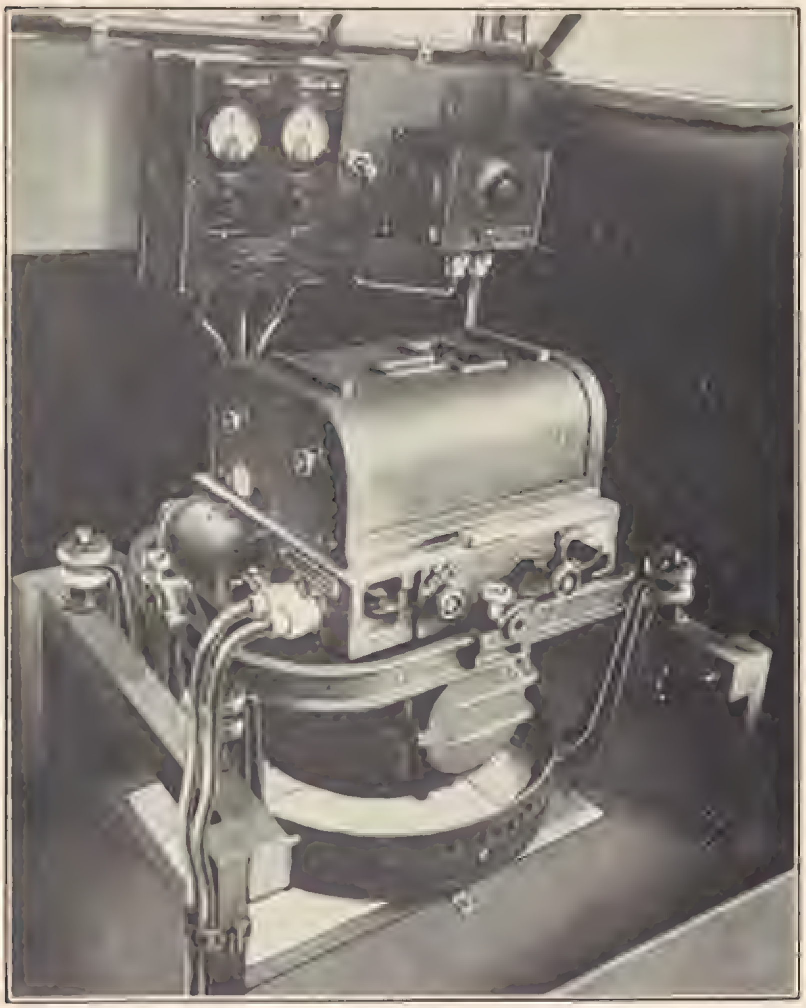
longitudinally—that is, if he has the nose up or down off the level. Supported in this frame and in the same manner is another frame which works in the opposite direction; that is, the points of suspension are on the opposite side from those of the supporting frame, which allows the camera to be kept level if the pilot has the ship off-level laterally, or has one wing low. These two motions working together will allow the focal plane of the camera to be kept level in relation to the earth's surface regardless of the bumps throwing the ship off-level.

There is still another movement to this mount, which is frequently used, namely, the one which allows the camera to be turned on its vertical axis without removing it from the mount. This is a very necessary movement in mapping, for often while flying a strip it is necessary, on account of the wind, to crab the ship. By turning the camera on its vertical axis we can still secure pictures which are straight in relation to the strip. When a camera has been turned on its vertical axis by this latter movement of the mount it may be tightened and locked in this position by a set screw at the side of the camera support. When the camera is first set in its canvas-lined support, it is tightened by a winged bolt so as to keep it from slipping from side to side. Any adjustment necessitated by the crabbing of the ship is made by turning the camera together with that part of the mount which grasps the camera.

The Mount for the K-3 Camera.—The K-3 camera mount operates on the same principle as the mount for the K–1, but is smaller and more compact, being made to fit the K–3. It has the same rectifying movements as the K–1 mount and has practically the same adjustments.

The Mount for the T-1 Camera.—The T-1 camera has two trunnions, one on either side of the flat surface of the camera and fitted in such a manner that they are above the center of gravity. The trunnions are arranged so as to fit into the receiving sockets of the special camera mount, which is part of the camera equipment. The oblong wooden frame which supports the camera is hinged on one side and fastened with a winged bolt. This must be open and the camera inserted from the bottom with the trunnions fitted into the sockets in the side of this frame. This frame in itself with the camera trunnions allows the motion which takes up for the plane being off-level laterally. The frame is fitted in turn

to two circular arms which form the support for the framework by means of two other movable joints on the opposite side from those



Courtesy Fairchild Aerial Camera Corporation

FIG. 29.—INSTALLATION OF K-3 AUTOMATIC RECORDING CAMERA

(View finder omitted.) Intervalometer at right end of instrument board.

which hold the camera in the wooden frame and which in turn allow the camera to be moved to take up for the plane being off-level longitudinally. This entire wooden frame supporting the

camera is moved upon these circular arms by means of sliding parts, one on each side, which allow the camera to be moved on its vertical axis and take up for the crabbing of the plane. These circular arms are fitted to the supports in the plane by means of the same type of cushion supports used in the K–1 mount.

The Oblique Mount.—The aerial camera used at the present time is much too heavy and cumbersome to hold over the side of

U. S. Army Air Corps

FIG. 30.—K-6 CAMERA AND MOUNT FOR OBLIQUE PHOTOGRAPHS

the cockpit and if rested on any part of the airplane the effect of vibration will be too great. An oblique mount is constructed, therefore, on which the camera can rest. This mount is usually home-made. An oblique mount constructed as the one in the illustration will prove very satisfactory. The shock absorber cords between the two posts not only absorb the vibration, but enable the photographer to move the camera in any desired direction. The nut and bolt are used to attach the mount to the cock-

pit. One addition is recommended, that is, that a second shock absorber cord be attached to the end of the camera rest so that, when the camera is not being used, this cord can be brought over the top of the magazine and attached to the other end of the camera rest. If the flange on the cone of the camera used to keep the shock absorber from slipping is not provided one can be easily constructed from a sheet of aluminum. This flange should be shaped so as to fit the cone of the camera, thus making a permanent attachment to the cone unnecessary.

Gyroscope.—During the past few years several efforts have been made to use the gyroscope in connection with camera mounts. Working on the principle that once a camera is placed with the long axis perpendicular to the earth's surface and once the gyroscope is set in motion the camera will stay in the same relation to the earth's surface regardless of the motions of the aircraft in which the camera is mounted. The gyroscope consists essentially of a heavy ring or disk rotating at a high rate of speed on an axis free to point in any direction. So far these efforts have been unsuccessful.

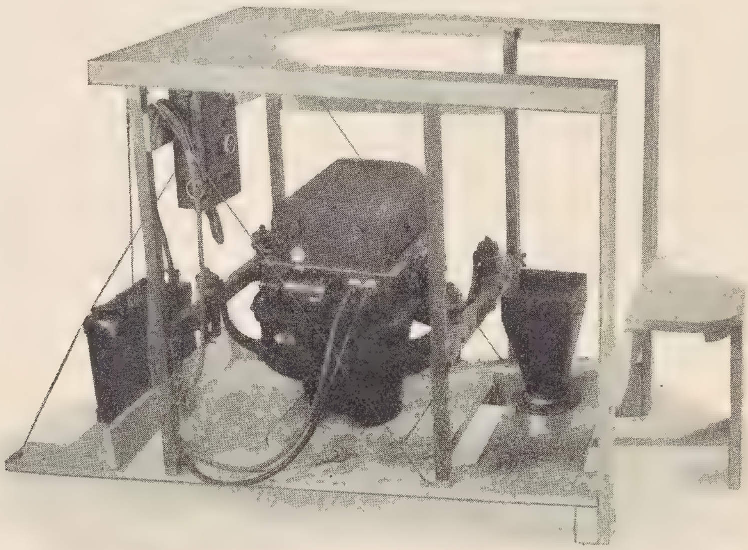
CAMERA INSTALLATION

Installation of the K-1 or K-5.—There are two perforated strips attached vertically to the longerons directly in front of the photographer's seat on either side of the aperture in the floor of the cockpit through which the nose of the camera is pointed. A cross-piece, bolted by wing nuts to these uprights, is on each side and parallel to the longerons. The ends of the suspension are fastened to these cross-pieces by screw clamps. After the suspension has been placed in the cockpit in this manner, the camera is placed in the suspension in the cloth band designed to hold it so that the timing mechanism on the side of the camera will be on the photographer's right. If the band is loose, it should be tightened by the means of a set screw. The Venturi tube is attached on the outside of the fuselage near the photographer's cockpit and parallel to the longerons. The small end of the tube points toward the nose of the ship. The rubber hose is then connected to the Venturi tube and the head of the camera.

Installation of View Finder.—The ball end of the standard view finder or sight fits into the socket joint fastened to the small aperture in the bottom of the fuselage which is between the

observer's feet and the camera aperture. By turning the ring in the socket joint any degree of stiffness can be given to the finder.

Installation of the K-3 Camera.—With camera supports opened, set the camera in the mount and swing the cap over the bearing. Then tighten the knobs, thus producing a slight tension to hold the camera in its position. The mount is attached to wooden cross-bars securely fastened to the sides of the airplane and at a height that brings the end of the cone just above the floor of the cockpit.



U. S. Army Air Corps

FIG. 31.—K-3 CAMERA INSTALLATION IN DUMMY COCKPIT—WITH VIEW FINDER

Intervalometer.—The intervalometer should be hung in any convenient position on the side of the cockpit which the observer can easily reach. Before making any electrical connections the setting knob on the front of this unit should be depressed and turned in a counter-clockwise direction to the "stop" position.

Signal Lights.—Two 6-volt lamps should be wired in series and plugged into the socket provided for this purpose on the intervalometer. These should be mounted conveniently as signals in the pilot's and observer's cockpits.

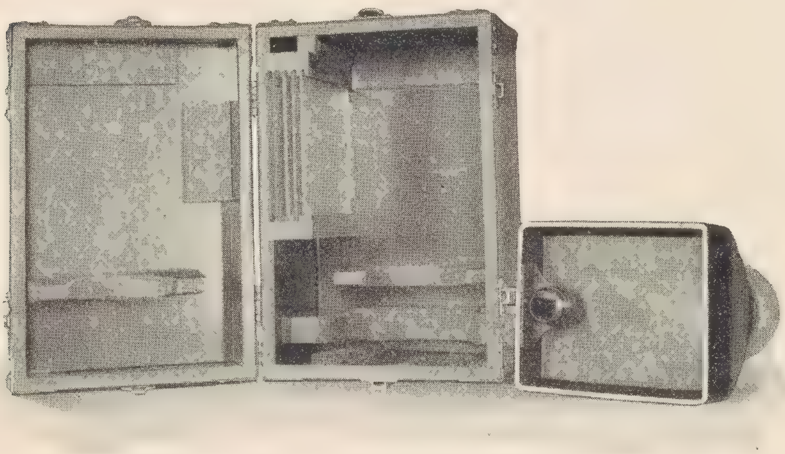
Battery and Connections.—A 12-volt storage battery should be set in any convenient location and connected to the proper socket

on the camera by the two-wire cable provided. The proper sockets on the camera and the intervalometer should be connected by the three-wire cable provided. All connections are marked on the camera.

VIEW FINDER (VERTICAL)

The vertical view finder is essentially a fixed focus camera with a ground-glass replacing the plate or film. The cone is $8\frac{1}{2}$ in. in length.

The nose of the view finder is constructed in the shape of a ball. A metal cup fits in the aperture of the photographer's cockpit.



U. S. Army Air Corps

FIG. 32.—VERTICAL VIEW FINDER (AT RIGHT) AND CASE (AT LEFT)

The ball end of the view finder is placed in this cup forming a ball and socket joint. A ring screws down on the cup so that the connections can be made sufficiently tight. This holds the view finder in the position as placed by the operator. The view finder is leveled with a circular spirit level fixed on the rear end of the cone.

The ground-glass in the rear end (top side) of the view finder is interchangeable. Each ground-glass is etched with parallel lines (with half-inch intervals) running vertically across the glass. There are two parallel lines running lengthwise. The distance between the two horizontal lines is so measured that an image passing from one line to the other will give a 60 per cent overlap.

Each ground-glass is designed for a camera of a certain focal length. The horizontal lines on the ground-glass vary with the focal length of the camera to be used, and the film or plate size.

The distances between the lines for certain focal lengths are:

20-in. focal length	1.20 in.
12-in. focal length	2.00 in.
$6\frac{1}{2}$-in. focal length	2.75 in.

CHAPTER VII

THE LENS

THE essential features of a lens for aerial photography are great rapidity (at least *f.* 4.5) and freedom from all possible aberrations. It is generally considered that pictures are sharp when the circle of confusion is about 1/1000 of the focal length of the lens. For a lens of 10-in. focal length this would be 1/100 of an inch. The circle of confusion for lenses used in aerial photographic work should be well above 1/200 of an inch. Compared with lenses used for ground work those used in the air are generally of longer focal length giving greater magnification with a smaller field of view. The ground to be photographed is always at practically an infinite distance from the camera and consequently the lens is almost always fixed at the equivalent focal distance from the sensitized material. The long focal length lens necessitates a long cone, results in a comparatively small area being covered, and tends to increase the magnitude of shutter distortion. The short focal length lens, on the other hand, with a wide angle of view produces noticeable edge distortions when a photograph is taken with it over a terrain not absolutely flat.

Optics is that branch of science relating to the nature and laws of vision. The lens, therefore, is the eye of the camera and consequently the most important part. The photographic quality of a picture depends in large measure upon the construction of the lens used. When obtaining a camera a thorough investigation of its lens should be made by a competent technician.

A Lens Defined.—A lens may be defined as a portion of a refracting medium (which may be any transparent substance) bounded by two spherical surfaces which have a common axis. In other words, a lens is usually a piece of glass whose two faces are parts of spherical surfaces.

Classes of Lenses.—A **convex** or **converging** lens is thicker in the middle than at the margin and is called converging

because it causes parallel rays of light to converge or focus at a point.

The other general type of lens is called the **concave** or **diverging** lens. It is the reverse of the convex lens. It is thinner in the middle than at the margin and causes the parallel light rays to diverge. In the range between the convex lens and the concave are various forms of simple lenses.

Focal Length.—In order to obtain a clearly defined image, the lens must be a definite distance from the plate. This distance, when the object focused on is far off, is called the focal length. Focal length may be roughly defined as the distance from the lens to the point where the rays meet after refraction. In other words, it is the distance from the lens to the ground-glass in the camera when the lens is focused on an object at infinity, which, ordinarily speaking in the case of small lenses, is 100 ft. or more away. The focal length of a particular lens does not vary, but is fixed by the way the lens has been ground, that is, the curvature of the surfaces, and also by the kind of glass used in its construction. As a lens may be so made as to be of almost any focal length, by the term "size of lens" is often meant the focal length of the lens. Thus a 9-in. lens does not mean one whose diameter is 9 in., but one whose focal length is 9 in.

Necessity for Focusing a Lens.—The degree of refraction being fixed by the kind of glass used in the making of the lens and also fixed by the degree of curvature of the surface of the lens, it follows that rays that meet the lens at a more acute angle than others will emerge at a more obtuse one. This necessitates moving the lens farther from the ground-glass in order to improve the definition of the image of *near objects,* by which is meant objects at a distance of less than 100 ft. from the lens.

Defects in the Single Lens.—In the image formed by the single lens are serious defects as follows: Fine lines in the object will appear blurred in the image and no matter how carefully focused the image will not be sharply defined. The middle of the image will also be in better focus than the edges and a bright object will be fringed with color. These defects are called aberrations and the common ones, which include those just described, are:

1. Chromatic aberration.
2. Spherical aberration.

3. Coma.
4. Astigmatism.
5. Curvature of field.
6. Distortion.

1. Chromatic Aberration.—If a prism is placed in the path of a beam of light that is entering a darkened room, it will divide the beam into the colored rays of which the beam of light is composed. This separation, by means of a prism, of a beam of white light into its component colored rays is called dispersion. The band of colored light produced by the dispersion of a sunbeam is called the solar spectrum. Since the spherical surface of a lens may be considered as made up of an infinite number of triangles or prisms, when a ray of white light passes through the simple type of lens, the ray is broken up into its components, and the various colored rays are brought to a focus at different points. The red component, which is the ray of longer wave length, is brought to a focus at a point farther from the rear lens surface than the point at which the violet component, or the ray of shorter wave length, is focused. As a consequence, if such a lens were used, the blue and violet rays would be brought to a focus in the camera farther away from the ground glass than the orange, yellow and green rays. The blue and violet rays, although the most actinic, appear feeble to the eyes. The result is that focusing is effected principally by the aid of apparently the brightest, but really the least actinic rays, so that when the image is in focus to the eye only the green, yellow, and orange rays are in focus and the violet and blue rays are not. The effect of this is that on development the plate will give a blurred image (caused by the violet and blue rays not being in focus) although the image may have appeared to be perfectly sharp on the focusing screen. This failure of the colored rays to focus at the same point is known as **chromatic aberration.**

How Chromatic Aberration is Corrected.—The dispersive power of glass varies in different kinds, according to the ingredients which have entered into its composition. The refractive and dispersive powers of any kind of glass are not necessarily connected by any kind of ratio, two specimens of glass may have the same refractive index, but a widely different dispersion or vice versa. The extent to which the light ray is bent depends upon the refractive index of

the glass, which may be explained as follows: If the angle which a ray of light incident upon a transparent plane surface makes with the normal or perpendicular to the surface, and the angle which the ray makes with the normal after refraction is unused, it will be found that the ratio of the sines of these angles is constant for a given substance. This ratio is called the refractive index of the substance.

Crown glass and flint glass having different densities, vary in their refractive and dispersive powers, and it has been found that by cementing a concave lens of flint glass behind a convex lens of crown glass chromatic aberration may be corrected. Sometimes three or more lenses may be used in combination, the principle, however, being the same. A lens corrected in this manner is known as an **achromatic** lens, or one that is free from chromatic aberration.

2. Spherical Aberration.—Spherical aberration is due to the curved surface of the lens, and may be defined as the inability of the lens to bring the rays that pass through its edges or margin to the same focus as those that pass through its center. The effect of this, if uncorrected, would be that no matter how the ground-glass is placed, each point in the image would be depicted as a nebulous disk of light and these would all overlap each other, making it impossible to secure a sharp picture. The lens, in fact, would have no absolute focus, but rather a number of different and clashing foci.

There are two kinds of **spherical aberration**—**negative** and **positive.** The curve or curves of a lens determine whether the spherical aberration is negative or positive and also govern the amount of it. Convex lenses cause positive aberration and concave lenses give rise to negative aberration.

Correction of Spherical Aberration.—The elimination of spherical aberration is as follows: Select as the convex component of the achromatic combination a lens whose positive spherical aberration will equal or offset the negative spherical aberration of the concave component. By this method spherical aberration is only partially eliminated. It can never be entirely removed so long as spherical lenses are used. For ordinary purposes it is considered that it is sufficiently removed when the image of a point of light is rendered in the picture as a circle not more than 1/100 of an inch in diameter. In the high-grade lenses used in aerial photography, the degree of

correction is indicated either by a general indistinctness of the image or by a fairly sharp image covered by halo (fog). Stopping down the aperture will improve the performance of a badly corrected objective.

3. Coma.—Coma is present in a lens when the image of a bright point of light toward the margin of the field of view is distorted into a pear-shaped or coma-shaped blur. **Coma** is the spherical aberration of pencils of light going through the lenses in oblique direction. It is sometimes referred to as oblique spherical aberration or zonal aberration. Stopping down the lens reduces the amount of coma. It is corrected by very carefully choosing and designing the optical constituents and curves of the lens.

4. Astigmatism.—Astigmatism is the effect caused by the lens bringing oblique rays of light to two focal lines instead of to a single focal point. The result is that it is impossible to get both horizontal and vertical lines sharp at the same time near the margin of the plate, although the center of the image may be perfect. Astigmatism may be remedied to a great extent by the use of a small stop, but is corrected in high-grade lenses by carefully designed arrangement of the curves and thickness of their components. A lens so corrected is known as an **anastigmat.** Astigmatism, although seldom entirely absent from any lens, is more usually found in lenses designed to obtain great flatness of field. The introduction of Jena glass has enabled the optician to devise combinations in which the defect is almost entirely eliminated.

5. Curvature of Field.—Owing to the spherical form in which lenses are ground the image of a flat object is not formed on a plane or flat surface but on a curved one; thus it follows that when the middle of a picture is focused for at full aperture, the edges are out of focus and vice versa. The fault is known as curvature of field. It is corrected by designing the lens so that the focal length is somewhat greater for the edges of the field than for the center.

6. Distortion.—When a lens distorts, the straight lines near the edges of the field are not rendered as straight but curved. If the stop is placed in front of the lens the curving will be convex and a photograph of a square will show it as barrel-shaped. If, however, the diaphragm is behind the lens the curving will be concave and a square will appear pin-cushion-shaped. This defect is known as **curvilinear distortion.** It is corrected by mounting two similar lenses at opposite ends of a barrel with dia-

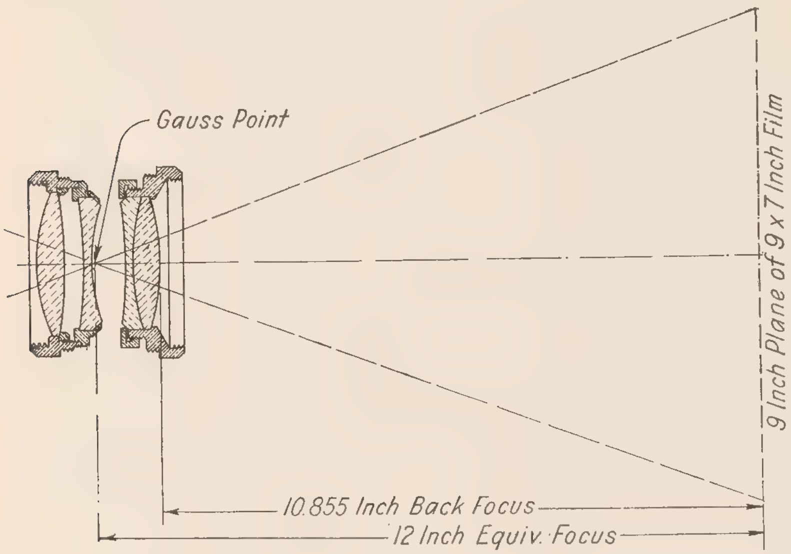
phragm midway between them, when the barrel-shaped distortion of one balances the pin-cushion distortion of the other. Such a combination of lenses is called a rapid rectilinear lens.

The Anastigmat Lens.—This is the general type of lens used for aerial photography. An anastigmat is free from astigmatism, and is well corrected for chromatic aberration, spherical aberration, and curvature of field. However, it must be understood that it is impossible to correct absolutely for any error, that is, to make the lens render the image of a point of light as a true point over the entire field of the objective. An approximation is all that can be expected. The result of any optical error is to make the image of a point appear as a circle of appreciable diameter, and the purpose of the lens designer is to reduce the diameter of such a circle, known as the "circle of confusion," to a size which will be inappreciable to the unaided eye, the ideal striven for being usually 1/200 in. Furthermore, this cannot be attained over the entire field of the lens, so the designer endeavors to attain this ideal over as large an angle as possible. Hence, when a lens is said to be corrected for any fault, it means that the circles of confusion due to this error do not exceed about 1/200 of an inch in diameter over the size of the plate for which the lens is listed. If used on a larger plate, the error will become apparent.

Composition of Anastigmat Lens.—As already stated, an anastigmat is free from astigmatism and is corrected for chromatic aberration, spherical aberration and curvature of field. In order to effect the correction of these aberrations such a lens must be composed of several simple lenses of different forms and of different kinds of glass.

General Construction of Anastigmat Lens.—These lenses are all known as "doublets," that is, they are mounted so that there is a front element and a rear element and, by unscrewing, either one or both may be removed. When the construction of the front element and the rear element is the same, as for instance in the case of the Protar, and Turner-Reich lenses, the lens is called *symmetrical* and either the front or rear element alone may be used. For example, in a 7-in. Protar the front or rear element when used alone would give a 14-in. lens, but of only half the speed of the doublet. Sometimes the Protar and the Turner-Reich doublets are combinations of two elements of different focal lengths. In such cases the doublets are called *convertible* lenses. Each doublet

then is really three lenses in one, consisting of the doublet which gives one focal length, the front element alone which gives another focal length, and the rear element alone, which gives still another focal length. The front and the rear elements are not always symmetrical, but sometimes are constructed differently, as in the cases of the Tessar and Heliar lenses. Such doublets or combinations are called *unsymmetrical* lenses and neither the front nor rear element can be used alone. The glasses making up the elements are in some cases cemented and in other cases not cemented.



Courtesy Eastman Kodak Co.

FIG. 33.—ANASTIGMAT LENS, CROSS-SECTION

The Gauss Point is the point from which the focal length is measured.

When they are cemented the lens is known as a *cemented* lens; and when not cemented, as an *air space* lens.

Speed of a Lens.—The speed of a lens is determined by two factors: first by the diameter of the effective aperture, which, practically speaking, is the width or diameter of the lens; and secondly, by the focal length.

The size of the image of the source is determined by the focal length—that is, the area on the plate over which the light admitted by the lens is spread. On these factors the speed of the lens depends. This speed is expressed according to what is known as the

f-system, which is the ratio existing between the diameter of the effective aperture and the focal length. For instance, if this diameter is 2 in. and the focal length is 8 in., the speed of the lens would be expressed under this system as *f*. 4, that is, focal length divided by diameter equals 4. Other things being equal, the amount of exposure at different stops necessary to take a photograph varies directly as the square of the *f*-value. If at stop or diaphragm opening *f*. 4, the required exposure is 4 seconds, at *f*. 8 the required exposure would not be twice as much, or 8 seconds, but would be 16 seconds as proved by the solution of the following equation:

$$f.\,4 \text{ squared} : f.\,8 \text{ squared} :: 4 : x$$

Depth of Focus.—The depth of focus is the distance—near to far—over which a lens will render sharp definition. Depth of focus decreases either as the size of the aperture increases or as the focal length increases. Photographs in which the object is near have not as much depth as those showing the object at a distance. All lenses having the same speed and focal length have the same depth of focus. Depth then is governed by:

1. Lens aperture or diaphragm opening.
2. Focal length.
3. Distance of object from lens.

With a given focus and object distance, the smaller the stop the greater the depth.

At a given object distance and diaphragm opening, the shorter the focal length, the greater the depth.

With a given focal length and stop, the greater the object distance up to infinity the greater the depth.

Angle of View.—The angle of view, so far as the size of the photograph is concerned, is the angle included between lines drawn from the opposite corners of the plate to the lens. Really, however, the angle of view of a lens is the angle included between lines drawn from opposite ends of the diameter of the circular field of a lens, through the center of the lens. The angle over which the lens gives a sharp image is dependent on the type of construction and design of the lens. Thus, the Tessar type of lens is designed to form a satisfactory image out to about 30 degrees from the center of the picture, while the series V Protar gives a good image to nearly 45 degrees. A Protar lens can therefore be used with a plate half again as large as a Tessar of the

same focal length. Lenses designed to cover large angles are known as wide angle lenses.

Covering Power.—Covering power is the ability of a lens to form an evenly defined and illuminated image over the entire area of the plate. It depends upon the angle to which the lens is designed to give a good image and upon how well the lens is corrected for the various kinds of aberration already explained.

Definition.—Definition in a negative is that clear, sharp detail obtained by the use of a lens of correct formula, which has been made by expert workmen from the best materials. With a poor lens the definition may be improved by using a smaller opening.

Flare.—A flare spot or ghost is the effect produced by the reflection of rays of light from the lens surfaces, forming secondary images and rendering a fogged appearance of the negative.

Care of Lenses.—All lenses acquire, sooner or later, thumb marks, grease spots, and particles of dust on the front and rear surfaces. Also, nearly all lenses take on in the course of time a grayish coating on all the inside elements, as well as on the outside elements. This coating, gray in color, is probably due to oxidation, and may be made more noticeable by the presence of oil vapor (from oil used on the diaphragm leaves) or from volatile matter emitted by the optical varnish used inside the lens. It is probable that the coating is principally oxide formed on the glass. When cleaning it is very essential that no solvent such as alcohol be used as this is liable to dissolve the varnish on the lens mounting, with the result of smearing the varnish over the lens surfaces. Usually it is sufficient to breathe on a lens and then wipe it carefully with an old, well-washed linen handkerchief. The lens should first be dusted with a handkerchief or with a camel's hair brush to insure that there are no particles of dust or grit on the lens surface, as such particles would cause scratches during the polishing operation. It is quite possible to overdo the cleaning and even to damage the lens by too much rubbing and polishing. One of the signs of a good lens is that the surface of the glass looks black when held against a dark object. If it looks gray instead of black after being breathed upon and wiped as explained, it is a sign that the fine polish originally given the lens has been worn off by too much wiping and cleaning and that the surface is covered with a multitude of fine scratches. This tends to a loss of brilliancy in the photographs made with the lens. A surface that has been very badly

scratched will give an effect very much like that given by a dusty lens. The only remedy is to have the lens repolished by the manufacturer. If a spot is found on a lens which will not loosen up with moisture from the breath and careful wiping it is possible that it is a corrosion mark which can be removed only by repolishing. Airbells or bubbles in the glass are not serious. They are unavoidable in the manufacture of some kinds of optical glass. They do not in any way interfere with the definition obtainable or the good performance of the lens.

Lenses if kept in a reasonably dry place will suffer practically no deterioration. It is advisable not to keep them where it is too warm, or near steam radiators or other powerful sources of heat. It is advisable that the smaller lenses be kept wrapped in tissue paper and enclosed in the usual pasteboard box which is regularly supplied by the manufacturer. There is a tendency to throw the outer container away and place the lenses on a shelf or in chests without protection. The original wrapping furnished by the manufacturer should accompany the lens until the lens is actually mounted in the camera in which it is to be used. In the case of the larger lenses it is desirable that the lens cap for the front cell, which is furnished by the manufacturer, be supplemented by a second cap to cover the rear cell. This affords more complete protection. It is advisable in storing lenses that they not only should be kept where it is dry and reasonably cool, but that the atmosphere itself should be free from acid fumes or other gases. Lenses in use are not susceptible to the season changes in temperatures as found in various sections of the United States. So far there is no indication that the change in temperature from ground temperature in summer to the low temperatures encountered at 30,000 feet produces any injurious results on such lenses that have been taken up in the air.

The only deterioration that takes place due to age is possibly a gradual darkening of the Canada balsam with which many types of lenses are cemented together. In the uncemented lenses there is, of course, no such change. This action results in a yellowing of the balsam and has the same effect as a ray filter on the lens, resulting in a slowing down of its speed. This may be rectified at any time by uncementing the lens elements, cleaning them, and recementing them with fresh balsam. This is a factory operation. More recently lens manufacturers have produced a better quality

of balsam, giving more attention to bleaching, and it is not likely that storage will cause deterioration to such an extent that it will be necessary to re-balsam more often than once in ten years or even longer. The only change that takes place on account of age is the accumulation of a grayish coating on all of the surfaces, inner and outer, of the lenses. Certain glasses making up a lens are more susceptible to this oxidation than others. This grayish coating is very easily removed by the simple process of polishing with a soft linen handkerchief or with a lens paper. A solution of alcohol and water is sometimes used for cleaning the lens surfaces. It is important that the proportion of alcohol be small, as the varnish of the lens mounting may be attacked.

The Spectrophotometer may be used to determine what proportion of the spectrum is absorbed by the glass and cement of a lens. Figures obtained from inspection of new lenses may be compared with figures obtained after lenses are in storage for some time, and from these the lenses may be restored to their former condition by overhauling when necessary.

Testing of Lenses.—The aberrations of modern anastigmats are so small that rough-and-ready tests are valueless. Some indication, however, of the performance of the lens can be obtained by photographing a brick wall with the camera accurately placed with the plate parallel to the wall.

If the lines of the bricks near the edges of the plate are not straight distortion is present.

If the focusing screen must be moved in or out from the position of best focus in the center, to get the edges sharp, curvature of field is present.

If at the edges of the photograph the vertical lines are sharp at one setting and the horizontal lines at another astigmatism is indicated.

Part II

FINISHING THE PHOTOGRAPHS

CHAPTER VIII

THE DESIGN OF A PHOTOGRAPHIC LABORATORY

THE construction of the photographic laboratory will, of course, vary greatly with circumstances and available location. The plan given here is somewhat elaborate. Each activity is given a separate room, some of which could be combined. The photographic laboratory should be constructed at the flying field for reasons which are obvious. However, it might be noted that one important factor is that flying fields are usually located some distance from the dirt and fumes of cities. The following plan is based somewhat on the army "photo hut."

For convenience the ground work is divided into nine departments, namely: aero-film developing, aero-film drying, contact printing, print washing and drying, enlarging and rectifying, drafting (mosaic making) and copying, chemical laboratory, supply department, camera repair and administration. In this plan, each department has been separated so that the work of one will not interfere with that of another, but, as stated before, where the work is similar the departments may be combined—for example, the contact printing and enlarging, and camera repair and supply. The following is a description of the design as planned for department rooms. There are other plans which may suit different conditions as well as or better than the following plan.

The Aero-Film Developing Room.—This room is 16 by 10 ft. The floor is constructed of concrete sloping to a drain at one corner of the room. A sink is formed by making the sink floor 1 ft. lower than the remainder of the floor. This sink is 16 ft. long by 4 ft. wide running the entire length of the north wall. The walls and ceiling are constructed of wall board (celotex, insulite, beaver board or like materials) and painted a dull black. The seams on the walls and ceiling are covered with narrow wood stripping. The concrete floor should extend 1 ft. above the surface so as to form part of the wall. A wooden sink, 4 ft. in each dimension, is

constructed for washing film. This sink is placed on four 7 × 2-in. sills so that the water can run beneath it. A 1-in. pipe is coiled flat so as to fit the bottom of the washing sink. One end of this pipe is plugged, the other end connected to the water supply. Small holes are drilled on the top side of the coil every 2 in. By using

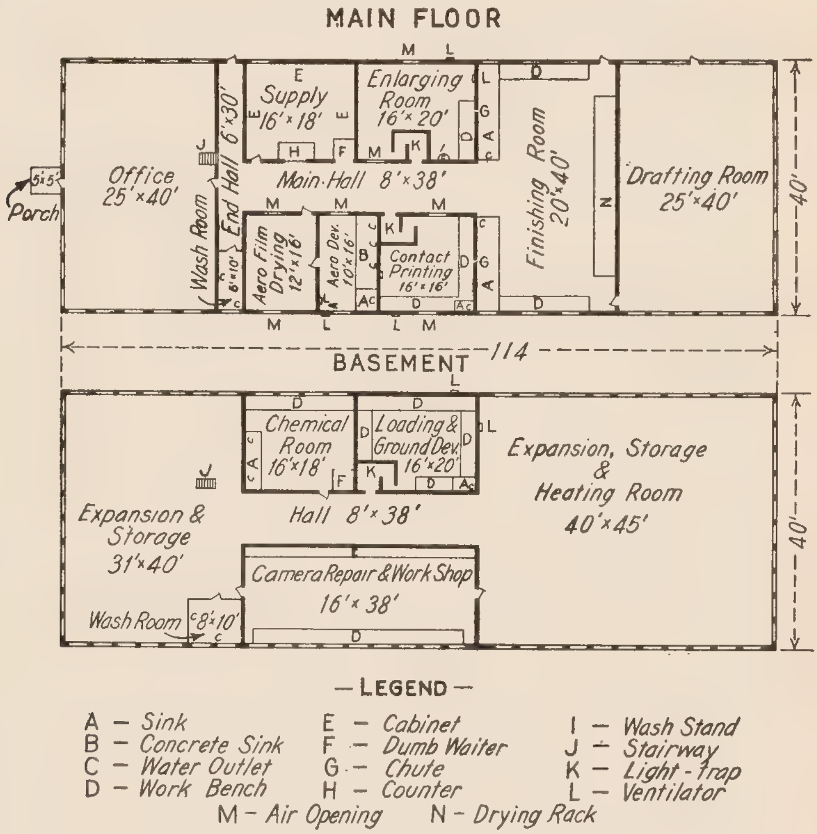


Fig. 34.—Design of Photographic Laboratory

this coil, when the water is turned on and the apron containing the film is placed over it the water will come through the roll of film in the bottom of the sink and flow over the top. The washing sink is placed in the concrete sink at the end where the floor drain is located. The door to the developing room is located in the center of the south wall. This doorway enters into the film drying room

and is latched from the inside. The illumination is furnished for this room by one ceiling light. The water supply is furnished by a pipe extending the entire length and 5 ft. above the concrete sink. There is an outlet in this pipe for each tank used in developing. For the ventilation of this room, see the paragraph on "Ventilation."

The Aero-Film Drying Room.—This room is 12 ft. wide by 16 ft. long and is located on the south side of the developing room. A drying reel is placed on or near the east and south walls. The ceiling and walls are constructed just as in the developing room. The floor is concrete, sloping to a drain in the northeast corner. The room is entered by a door from the hall. This room is illuminated by a ceiling light and a row of four lights equally spaced behind each drying reel so that the film may be inspected while drying. These lights are on separate switches. The two drying reels are the only equipment in this room.

The Contact Printing Room.—This room is on the north side of the developing room. It is 16 ft. wide by 16 ft. long. The walls and ceiling are constructed just as those of the developing room. The floor is concrete and slopes to a drain in the southeast corner. This room is entered from the hall through a light trap. Two work benches are constructed extending the entire length of the east and north walls. These benches are 3 ft. high and $2\frac{1}{2}$ ft. wide. A sink, 2 ft. wide, 3 ft. long, and 8 in. deep is sunk in the work bench at the northeast corner. Shelves 10 in. wide running the entire length of the two work benches are placed on the walls 3 ft. above the benches. The room is illuminated by an indirect lighting system which consists of a trough containing four lights, two of which are red and two white. The red lights and white lights are on separate switches. Four light plugs are arranged so that one will be near the location of each printer. The contact printer or printers and the trays for the development of the prints are placed on the work benches. This room also will contain the T-1 printer and the copying printer. In the wall next to the print drying and washing room and above the workbench in the printing room a chute is constructed in such a manner that the prints after being developed and fixed may be dropped into the chute and will fall in the washing tank located in the print washing and drying room. This chute is slanted at a 65 deg. angle from the horizontal. A door is placed on the chute on the printing room side and a slide is fur-

nished at the other end. For the ventilation of this room see the paragraph on "Ventilation."

The Print Washing and Drying Room.—This room is on the north side of the contact printing room and extends the entire width of the building. Its dimensions are 20 by 40 ft. The walls are made of wall board and painted white. The floor is of concrete. There are two wooden sinks in this room, both placed against the south wall, one on the west side of the room, and one on the east side. These sinks are 16 by 4 ft., and $3\frac{1}{2}$ ft. deep. The water supply flows in at the bottom and overflows through a drain 6-in. from the top. There are three equally spaced windows on the east and west sides of this room. These windows are each 3 ft. wide and 6 ft. high and 5 ft. above the floor. A work bench, 4 ft. high, 15 ft. long, and 3 ft. wide is placed against the wall beneath the windows on each side of the room. There are two shelves under each table extending the entire width and length of the table. There is a print drying rack 30 ft. long, 6 ft. high, and 4 ft. wide placed against the north wall. This room is illuminated by a ceiling light in the center of the room and two over each work bench.

Drafting (Mosaic) and Copying Room.—This room is 25 by 40 ft. It extends across the entire width of the building and is located next to and on the north side of the print drying and washing room. This room is the north end of the building. The building is facing north and south in order to give the best lighting conditions. On the east, west, and north sides the windows are continuous with the exception of a space for a door located in the center of the west side. The lower part of the windows is 3 ft. above the floor and they extend to 2 ft. from the ceiling. The door entering into the print drying and washing room is located in the southeast corner of the drafting room, thereby allowing approximately 33 ft. of wall space for the copy board. The walls and ceiling are made of wall board painted white. The floor is of concrete covered by a wood floor. The illumination is provided by four ceiling lights and there are four wall sockets in which lamps may be attached. The equipment in this room will include drafting tables, one large table (on casters) about 10 by 6 ft. for mosaic work, a copy board and a copy camera.

The Enlarging and Rectifying Room.—This room is next to and on the southwest side of the print washing and drying room (across the hall from the printing room). The dimensions are 16

by 20 ft. The walls and ceiling are constructed the same as those in the printing room. The floor is concrete, sloping to a drain in the southwest corner of the room. The room is entered from the hall by a light trap placed in the center of the wall. There is a work bench 10 ft. long, 3 ft. wide, and 4 ft. high placed by the wall next to the finishing room. There is a washstand in the corner by the bench and the light trap. The spigot furnishing the water supply is raised 1 ft. above this stand. The illumination is furnished by an indirect lighting system constructed the same as the one in the printing room. There are also six wall plugs, two over the work bench, two on the west wall, and one on each of the remaining walls.

The Supply Department.—This room is located next to and on the south side of the enlarging and rectifying room, and its dimensions are 16 by 18 ft. The walls and ceiling are made of wall board and painted white. The floor is concrete covered by a wood layer. There is a 3 by 5-ft. window in the outside wall in the upper southwest corner. In the northeast corner a dumb-waiter, 4 ft. square, comes up from the basement. There is a door, 3 by 6 ft., entering into the hall in the east wall at the south corner. Between the dumb-waiter and the door an opening, 4 ft. wide and 4 ft. high and 4 ft. above the floor, is cut in the east wall. A counter, 6 ft. long and 3 ft. wide, is attached to the wall level with the bottom of the opening. Beneath the counter four shelves the same size as the counter are also attached to the wall and equally spaced. The remaining wall space, except a space of 5 ft. in front of the window, is covered by cabinets. This room is illuminated by a ceiling light.

The Halls.—The main hallway extends from the print drying room to a second hallway, forming a T at the end of the supply room and the aero-film drying room. The main hallway is 8 ft. wide and is illuminated by three ceiling lights. The second hallway is 6 ft. wide and extends across the width of the building. The east end of the second hallway is partitioned off for 10 ft., making a wash room. At the west end of the hallway a door leads to the outside of the building. A stairway going to the basement starts in the second hallway.

The Office.—The office extends across the entire width of the south end of the building. This room is 25 by 40 ft. and its construction is the same as that of the drafting room except that the

door to the laboratory enters into the second hall and the door leading to the outside of the building is in the center of the south end, opening onto a small covered porch. This room can be partitioned off into several private offices. Also a small receiving room can be partitioned off.

The Basement.—The basement extends under the entire length and width of the building and the foundation extends 3 ft. above the ground. The walls are 12 ft. high. The entire basement is constructed of concrete. It is partitioned off into the following rooms: chemical room, camera loading and ground developing room, camera repair room, heating plant, and extra supply room.

The Chemical Room.—The chemical room is directly under and has the same dimensions as the supply room. The dumb-waiter starts from this room and is in the same relative position as in the supply room. The partitions forming three walls are made of wall board and are painted white. Windows run the entire length of the outside wall, extending from 6 in. above the ground to 6 in. from the ceiling. The door enters into the hall and is next to the dumb-waiter. A sink, 10 by 3 ft. wide, and 1 ft. deep, and raised 4 ft. above the floor, is placed against the south wall in the southeast corner. Spigots for hot and cold water are placed above the sink. A work bench, 3 ft. wide and 4 ft. above the floor, runs the entire length of the rear wall. The space below the work bench is occupied by a cabinet. The space along the north wall is also occupied by cabinets 2 ft. wide and 6 ft. high. There is a gas lead extending over the work bench to which is attached a two-burner hot-plate. The illumination is furnished by a ceiling light and two drop lights over the work bench.

Camera Loading and Ground Developing Room.—This room is next to and north of the chemical room; in dimensions it is 16 by 20 ft. The walls are constructed of wall board in the same manner as those in the printing room. This room is entered through a light trap from the hallway. A sink, 3 by 4 ft. long, 1 ft. deep, and 4 ft. above the floor, is placed in the northeast corner. Work benches, 3 ft. wide and 4 ft. above the floor, extend around the remainder of the wall space. Shelving, $1\frac{1}{2}$ ft. wide and $1\frac{1}{2}$ ft. above the work benches, is attached to the wall and extends the entire length of the work benches. The room is illuminated by an indirect lighting system the same as that used in the printing room.

The Camera Repair and Work Shop.—This room is on the opposite side of the hall from the chemical and camera loading room and is 16 by 38 ft. It extends under the contact printing room, the aero-film developing room, and the aero-film drying room. The partitioned walls are made of wall board and are painted white. The windows extend the entire length of the outer wall. They are the same size as the windows in the chemical room. A work bench, 4 ft. high, 3 ft. wide and 36 ft. long, is placed against the outer wall. Cabinets extend the entire length of the west wall. These cabinets are the same size as the ones in the supply room. The shop is entered at either end by doors placed in the center of the end walls. The room is illuminated by ceiling lights and three equally spaced plugs are placed above the work bench.

The Remainder of the Basement.—The remaining space in the basement, located at each end of the series of the aforementioned rooms, is used for storage and the heating plant. The heating plant can occupy any portion of this space, provided that the smokestack does not interfere with any of the windows, especially those of the drafting room. Oil should be used as fuel in the heating plant as coal will make much more dirt, rendering it more difficult to handle the sensitized material.

Location of the Laboratory.—Assuming that the photographic laboratory is to be located at the flying field, the outside dimensions of the building need not be considered since a building plot of any reasonable size should not be difficult to obtain in the vicinity of a flying field. This plot should not be so near to any other building that the light may be interfered with, especially at the north end.

Future Additions.—The design given herein allows for considerable expansion within the structure. It was for this reason that temporary rather than permanent partitions were specified. This factor will allow considerable change to be made in the size and shape of the rooms. Changes will probably be necessary as the work increases or equipment of new design is developed. The space that was left in the basement can be used for several additional dark rooms. It will be better to move or add more dark rooms to the basement rather than other rooms as light is not a factor to be considered when locating a dark room. Another available space is that occupied by the office. It is not absolutely necessary that the office be included in the laboratory building. If extensions are needed it is recommended that they be extended

from the south end, or, if ground is not available in that direction, wings can be extended from the center portion.

If the building is located at the flying field additional stories will not be permissible. Most flying fields, at the present and probably for some time to come, will limit the height of their structures to one story.

VENTILATION, LIGHT, AND WATER SUPPLY

Ventilation.—Ventilation is obtained in the dark rooms by making an opening at the floor and one at the ceiling, the one at the floor being slightly smaller than the upper one. The air enters through the floor opening and is exhausted by an exhaust fan through the top opening. Both openings must be made light-safe and still retain their efficiency as ventilators. This is accomplished by making use of the fact that light travels in straight lines. The inside of the light trap should be painted dull black in order that its surfaces will not reflect light.

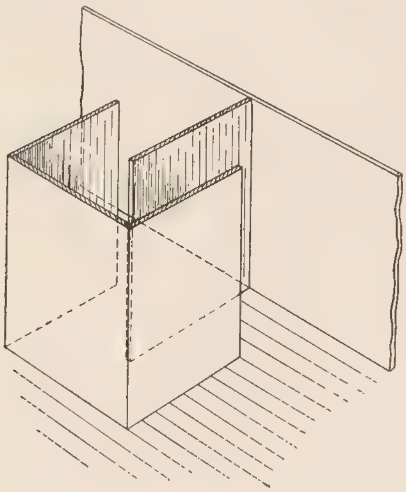


Fig. 35.—Light Trap

Entrances to Dark Rooms.—Dark rooms are usually entered through a light trap. The construction of this light trap is also based on the fact that light rays travel only in straight lines (see illustration of "Light Trap"). The light trap is painted a dull black.

Sinks.—The sinks included in these plans are constructed of wood and are unlined and unpainted. There are several woods that can be used. Among them are plain Louisiana cyprus and California redwood. If nothing else is obtainable white pine will serve as a material. The joints of the sink should not be made tight or the sink will warp and buckle when filled with water. Wood sinks should never be allowed to dry out. The sink should be strengthened by wooden clamps. These clamps should run the entire

height of the sink at the end on each side. The clamps are made of wood and are held together by several steel rods threaded and fitted with a nut at each end. The boards running the length of the sink should be extended past the end board about 2½ in. at each end. Holes are then bored in the extended part and in the clamps so that they coincide with each other. The rods are run through these holes and the nuts drawn tight.

Tanks for filtering chemicals and mixing hypo can be constructed in the same manner as the sink just explained. Stretched over this tank is a filter bag made of muslin. The bag should hang into the sink about 6 in. but should not dip into the solution. A filter bag can be made by sewing hems on each end and sides of the bag. Four steel rods of sufficient length slip through the hems so that the two end rods will rest over the top of the tank and the end of the side rods can be slipped through screw-eyes screwed in the side of the tank near the edge and about 2 in. from the top.

Airing the Dark Rooms.—If some method is not used to air out the dark rooms they will become dank and musty, much the same as an old cellar, especially the aero-film drying room. Ventilation is accomplished by placing windows 3 ft. wide and 4 ft. high halfway between the floor and ceiling in the outside wall of each dark room. Strips of wall board 5 ft. wide by 6 ft. high are clamped over these windows on the inside of the dark room. The clamps are made of four boards 1 in. wide, two of which are 7 ft. long and 1 in. thick. The other two are 6 ft. long and ½ in. thick. The clamps overlap at the corners when placed on their respective edges of the wall board. A notch 1 in. wide and ½ in. deep is cut in the clamps, which are 1 in. thick. At these junctions holes are bored through the four clamps and the wall board. Four rods are sunk in the wall at points which will coincide with the holes bored in the wall board, when the board is placed over the window and extends evenly on all sides. The four rods extend from the wall a sufficient length to go through the wall board and clamps and have an inch to spare. This additional extension is threaded. The board and clamps are then slipped over the extending rods and are held in place by a washer and wing nut. If the wall is at all uneven, strips of felt should be pasted with rubber cement over the edges of the wall board on the side next to the wall. It is also advisable, and included in this plan, to cut a similar aperture in the hall wall of the dark rooms and close it in the same manner as just explained for

the window. The rods, in this case, are run through the wall board wall. Blocks, 6 in. square and $\frac{1}{2}$ in. thick with a hole bored in the center of each, are slipped over the hall end of the rods (this end of the rod is also threaded) to serve as a washer. A nut is also screwed on this end of the rods. On every day when the sun is shining and when the dark room is not being used these two boards should be removed and the window opened. In this manner the dark room will be kept dry and fresh.

Water Supply.—It is very important that the water supply used in photographic work be pure to the extent that it will not change the value of the solutions. The best water for mixing chemicals is distilled rain water or water melted from ice or snow. In the regular supply such salts as bicarbonates, chlorides, sulphates of calcium, magnesium, sodium and potassium are often present. Before using a new water supply, it is advisable to have it tested. Colleges and state institutions will usually make this test. Commercial water purifiers may be employed, though often they fail to remove potassium and sodium salts. There are several methods for purifying water. Among them are boiling, distillation, and chemical treatment.

THE PHOTOGRAPHIC LABORATORY PLAN

General Explanation.—The following is a general explanation of features included in this design, which in themselves may not be self-evident. The plan is referred to several times as if it were in effect. This is done to emphasize the fact that the arrangement and design applied to the foregoing plan can be deviated from when other plans are used. This design, in all probability, is much more elaborate than can be expected in a photographic laboratory constructed by an organization starting in commercial aerial photography. The general principles, however, are applicable to any aerial photographic laboratory and certain features of this plan can be incorporated in a much smaller plan.

The floor and foundation are designed to be constructed of concrete for two main reasons, the most important being the great amount of vibration which is present when the floor is constructed of wood. This factor is especially important in the rectifying and drafting rooms where fine adjustments are made and precise work is undertaken. The other factor is that a concrete floor can be

washed with a hose, whereas this procedure would warp a wooden floor.

The rooms are so arranged that a roll of film will be developed in one end of the laboratory and the other necessary operations are completed in order and the finished product ends in the drafting room.

A washstand was placed in the enlarging and rectifying room instead of a sink as very little water is needed in that room and space is needed for other equipment.

The chemical room was placed in the basement in order to keep the chemical fumes as far as possible from the greater mass of the sensitized material.

Cabinets were provided, instead of open shelves, to keep out as much dust as possible and to provide a means of locking up the equipment and material.

Water was run in from the bottom, overflowing the top of the sinks. Water will change much oftener when this method is used than would be the case if the water were run in from the top and drained from the bottom.

Frigidaire should be specified for the supply room for the purpose of preserving the aerial film. Aerial film spoils very quickly when subjected to hot temperatures.

The dumb-waiter is to be used for lifting chemical solutions from the chemical room to the main floor. There are two doors in the dumb-waiter, one opening into the main hall, and the other one into the chemical room.

Cleanliness.—Keeping the photographic laboratory and equipment clean must be treated as part of the work and not as merely incidental. Although a degree of disorder may be permissible and is somewhat common among commercial studios, there is a wide gap between commercial photography and aerial photography. The laboratory work is in reality part of the office work of surveying and must be carried out with the same precision. Disorder and precision cannot be combined. The man in charge of a photographic laboratory, military or commercial, should make a thorough inspection at the close of each day's work. This duty should not be passed on to any one else.

Storing Film and Paper.—Sensitized material besides being sensitive to light is extremely sensitive to heat, pressure, etc., as follows:

1. *Heat.*—Heat produces fog on all light-sensitive material, especially when damp.
2. *Pressure.*—Pressure and friction will make the sensitive coating developable in the same way as light, producing what are known as stresses and aberration marks. Old paper is more sensitive to pressure than new.

GENERAL EQUIPMENT

The following is a list of general equipment that will probably be needed in connection with the photographic work within the laboratory.

Electric fans, 16-in., non-oscillating, 110 volts	6
Rubber hose (garden hose), 20-ft. lengths	4
Magnifying glass, 3 in.	1
Graduates, 32 ounce	10
Graduates, 8 ounce	2
Hydrometers, photographic	1
Instruments, drawing set	1
Soldering torch, 1 qt. size	1
Soldering iron, 1 lb.	1
Mortar and pestle, 16 ounce	2
Pans, stew for heating chemicals, 2 qt. size	4
Pans, stew for heating chemicals, 1 gal. size	2
Protractor, celluloid, 6 in.	1
Stirring rods, hard rubber, dozen	1
Print rollers, professional, 10-in.	2
Rules, 1 yard-stick	2
Rules, 1 ft.	4
Scales, soda, 5 lb.	1
Scales, studio	2
Shears, 10-in. pair	4
Squeegees, rubber, 8-in.	4
Tanks, enamel, developing, fixing, and washing, 7 × 9-in.	12
T-Squares, 42-in.	2
Trays, enamel, 10 × 12-in.	6
Trays, enamel, 21 × 25-in.	12
Thermometers, photographic	3
Triangles, celluloid, 45-deg., 8-in.	2
Triangles, celluloid, 60-deg., 10-in.	2
Trimmers, print, 10-in.	2
Aprons, dark room	10

Bottles, quart, glass stoppered	10
Bottles, gallon, glass stoppered	10
Brushes, bristle for painting varnish, 2-in.	2
Brushes, camel's hair, dusters 3-in.	3
Cloth, tracing, 42-in. roll	1
Cloth, cheese, bolts	1
Chamois skins	3
Cotton, absorbent, pounds	8
Clips, metal, Kodak Junior, dozen	1
Corks, assorted, gross	1
Envelopes, manila for mailing prints 8 × 10-in.	500
Envelopes, negative preservers, 9 × 7-in.	1000
Erasers, art gum	10
Ink, black, drawing, bottles	5
Ink, assorted colors, set of red, yellow, blue, green	1
Opaque, Gihons, cakes	1
Pins, push, gross	2
Plates, ferrotype, large	10
Pens, drawing, assorted, dozen	2
Paper, drawing, white, 42-in. rolls	1
Paper, tracing, 42-in. rolls	1
Crayon, grease, glass marking, dozen	1
Pencils, lead, retouching sets of 7 as follows: 6 B, 1 B, 2 B, 2 H, 3 H, 4 H, 5 H	1

CHAPTER IX

PHOTOGRAPHIC CHEMISTRY

Chemistry of Photographic Materials.—Photography is based on the fact that compounds of silver, especially its compounds with chlorine, bromine and iodine, are sensitive to light. Sensitive materials consist of a base of paper, film, or glass, coated with a light-sensitive emulsion.

Emulsion.—The emulsion is made by soaking gelatine in cold water until it is swollen and then dissolving it in warm water. The gelatine prevents the settling and keeps the silver bromide suspended evenly so that, as the silver is added, the gelatine will be full of evenly precipitated silver salt distributed throughout the solution. When this emulsion is coated on a support as paper, film, or glass and cooled, the gelatine will set to a jelly. When dried there is a smooth coating of dry gelatine containing the sensitive silver compound suspended within it.

Effect of Light on Sensitized Photographic Material.—When light is reflected from the subject and projected by the lens onto the sensitive photographic material, the image of the subject is impressed on this material by the light, changing the grains of silver compound which it strikes into so-called "sub-silver." When this sensitive material that has been so affected by light is placed in a developer the sub-silver, and only the sub-silver, is then converted into black metallic silver. When this developed sensitive material is placed in the fixing bath, the remaining unaffected silver grains are removed. If the sensitive material is a plate or film it becomes transparent except for the black metallic image. In the case of plate or film it is then termed a negative.

Chemical Reducers.—Chemical reducers are substances which have an affinity for oxygen and which can liberate the metals from their salts. A developing solution, therefore, contains a chemical reducer.

Not all substances which are easily oxidized are photographic developers, however, since a reducer, to be used as a photographic

developer, must be able to reduce the silver bromide which has been exposed to light. It must not, however, affect the *unexposed* silver bromide. Its affinity for oxygen must therefore be within certain bounds. It must be sufficiently strong to reduce thoroughly the exposed silver salt, and at the same time it must not affect that which has not been exposed. For practical purposes, the developing agents are limited to a very few substances, almost all of which are chemically derived from benzene.

Acceleration.—These developing agents cannot develop when used by themselves. In order for these agents to do their work, they must be in alkaline solution, and the energy depends upon the amount of alkali present. The developers of higher reduction potential, that is, those which bring up the image quickly, require less alkali than those of a lower reduction potential. These alkalies are known as accelerators. They speed up the action of the developer.

Restrainers.—Developers that are of an extremely high reduction potential when used in conjunction with an alkali make the image flash up, as they start the development very quickly even in the lesser exposed portions of the emulsions, and must be restrained or held back to prevent overdevelopment of those parts of the negative which are only slightly exposed, until the more heavily exposed parts of the negative are properly developed.

Preservatives.—A developing solution containing only a developer, an accelerator and a restrainer would very rapidly deteriorate from oxidation by the air.

In order to make the developer keep, there is added to the developing solution, in addition to the developer or developing agent, the accelerator and the restrainer, a preservative. For this purpose a chemical is employed which has a strong affinity for oxygen, being more easily oxidized than the reducing agent and thus protecting the developing solution from the oxygen of the air.

Agents in a Developing Solution.—Practically every developing solution must have at least one or more chemicals to act for each of the following agents:

1. Reducer.
2. Accelerator.
3. Restrainer.
4. Preservative.

Effect of Missing Agents.—The effect of one or more missing agents—the film being normally exposed and developed, is as follows:

1. *Reducing agent only:* There will be little or no visible result of development.

2. *Reducing Agent and Accelerator:* The oxidation stain will be great. There also will be a chemical fog due to the accelerator speeding up the action of the reducing agent.

3. *Reducing Agent, Accelerator, and Preservative:* Chemical fog due to the too fast development.

The above will show the necessity for all four agents mentioned in a developing solution.

Pyrogallic Acid.—Pyrogallic Acid, or pyro, as it is called in the formulas, is prepared in one of two forms, crystal or flake, and is distilled from gallic acid. For practical purposes the crystal form is used because the flakes may fly about and settle on sensitive materials thereby ruining them.

Pyro is a stain producing developer, developing slowly and deep and leaving a yellowish brown stain. Once the container is opened, Pyro absorbs moisture and oxidizes. When this occurs it is considerably weakened, and although it may sometimes be used it is generally unfit for photographic purposes. If only slightly oxidized, it may be used in solution by increasing the amount called for in the formula. The only means of determining the correct amount to be added is by mixing up solutions having varying quantities of this chemical and actually trying them out.

When pyro is oxidized the solution formed is considerably darker and will produce a heavier stain on the negative.

Metol.—Metol is a sulphate of monomethyl-para-aminophenol. It is a white, pinkish white, or light gray powder easily soluble in water. The solution has a poisoning effect upon the skins of some persons. After using a metol developer the hands should always be washed.

When mixed with an alkali, metol forms an extremely rapid developer, which gives a low density, is not sensitive to temperature, and yet while giving low density gives good detail. To offset the rapidity of the developer and get density, a chemical which has opposite qualities should be used with metol.

Hydroquinone.—Hydroquinone comes in grayish white or yellow prismatic needles which darken on exposure to light. It is

made from benzene which is first converted into aniline and then oxidized in order to obtain the hydroquinone. As a developer it is opposite to metol in all its properties, that is, it is a slow developer, gives great density, and not much detail, and is extremely sensitive to temperature. Thus metol and hydroquinone form an excellent developing solution because the desirable properties lacking in one are supplied by the other.

At a low temperature hydroquinone may crystallize in solutions, which either brings development to a standstill or slows down its action, resulting in loss of density in the negative. Increase in temperature beyond 65 to 70 deg. F. tends to excessive density and fog. Sodium sulphite, which is used as a preservative, has a marked effect upon hydroquinone development. The greater the proportion of sulphite the stronger will be the contrasts in the negative. Hydroquinone is very susceptible to restrainers and therefore they must be sparingly used with it.

An oxidized or stale hydroquinone will produce yellow stain, as in prolonged forcing of an underexposed negative in development.

PRESERVATIVES USED IN DEVELOPING SOLUTIONS

Sodium Sulphite.—Sodium sulphite comes in two forms, crystals and desiccated, free from water. The crystals contain about 50 per cent water, so if desiccated sodium sulphite is called for in a formula and crystals are used, twice as much as the formula calls for should be added.

Sodium Bisulphite.—Sodium bisulphite is used for the purpose of acidulating the preservative or the fixing bath. Often the amount of preservatives used prohibits the use of all bisulphite as too much acid would then be present.

Sodium bisulphite is the same as sodium sulphite except it has the acid atom.

Some stock developers will keep better if the preservative is slightly acid. In appearance bisulphite is the same as sulphite.

Sodium Metabisulphite.—Sodium metabisulphite is often used as a preservative. It is similar in appearance to sulphite and bisulphite. Sodium metabisulphite can be substituted for potassium metabisulphite in a formula, weight for weight.

Wood Alcohol.—Wood alcohol is another chemical which is used in developers for preservative purposes. It is used in cold weather to prevent the recrystallization of the metol in the developer. This is accomplished by the fact that metol is more soluble in alcohol than in water and is therefore more easily held in solution in alcohol.

The alcohol has no chemical action in the developer and does not affect the emulsion in any way.

ACCELERATORS

Sodium Carbonate.—One of the most commonly used chemicals for acceleration is sodium carbonate. This is common washing soda, but sodium carbonate which is commercially supplied for washing purposes is not sufficiently pure for photographic purposes. Dry, or anhydrous, sodium carbonate tends to absorb water. Monohydrated sodium carbonate, containing one molecule of water of crystallization, is the most stable form of sodium carbonate, since it neither dries out nor absorbs moisture. This form of carbonate is to be strongly recommended.

Potassium Carbonate.—Potassium carbonate can also be used as an accelerator. It is a stronger alkali and more soluble in water than sodium carbonate. It is less frequently used on account of being more expensive.

Sodium Hydroxide.—Sodium hydroxide may also be used as an accelerator. It must be handled very carefully as it is extremely caustic. It absorbs water very fast. After this salt has been exposed to the air it becomes covered with a heavy crust. This crust must be removed by scraping before weighing.

Potassium Hydroxide.—Is similar to sodium hydroxide except that it is more soluble in water.

Ammonia.—Ammonia was used considerably in the early days of photography, but is rarely if ever used now. It is a stronger alkali than the carbonates, but weaker than the caustics or the hydroxides.

Substitution of Alkalies.—When necessary any one of these alkalies can be substituted for another. Considering sodium carbonate as the basis of comparison or substitution because it is most frequently used, the following table of relative strengths can be used when substituting one for another:

Sodium carbonate (anhydrous)	1.00
(monohydrated)	1.17
(crystals)	2.70
Potassium carbonate (anhydrous)	1.30
(crystals)	1.64
Sodium hydroxide	.75
Potassium hydroxide	1.05
Ammonia (specific gravity 0.808)	.32

Effect of Varying the Amount of Alkali.—The amount of alkali governs the rapidity with which the developer works. If too much alkali is used the developer will overdevelop and produce chemical fog; but if too little alkali is present, it will be slow in its action.

Effect of Alkali on the Gelatine of the Emulsion.—Alkalies also soften the gelatine of an emulsion and therefore if a solution is used which is too alkaline it will produce an overswelling of the gelatine and in warm weather give trouble in the form of frilling and blisters on the negative.

This softening action of alkali on the emulsion has nothing to do with its developing properties.

RESTRAINERS

Too little restrainer will give the same effect as too much carbonate, and too much restrainer acts in the same way as too little carbonate.

Potassium Bromide.—Comes in white cubical crystals or powder and it is easily obtained pure.

Potassium Iodide.—Potassium iodide may be used as a restrainer, but it cannot take the place of potassium bromide. All soluble chlorides, bromides and iodides act as restrainers, and, in a lesser degree, alkaline citrates and sodium sulphite act as restrainers but the potassium or sodium bromide is generally accepted as the standard restrainer.

FIXATION AND FIXING MATERIALS

Hypo.—Sodium thiosulphate is the correct chemical name for this salt but it is known to photographers as hyposulphite of soda. Chemists give the name "hyposulphite of soda" to an entirely different substance. Hypo comes in clear crystals and is usually pure.

In the process of fixation, silver bromide is dissolved and the silver unites with the hypo to form "sodium silver thiosulphate." During the process of fixation two forms of sodium silver thiosulphate appear—at first one form which is almost insoluble and then another which is very soluble. As long as the fixing bath has any appreciable fixing power the soluble compound only is formed.

Acid Hardener.—Acid hardener is composed of: alum, acetic acid and sodium sulphite.

The hardener is always mixed in a solution separate from the hypo solution and it is then combined with it in certain proportions. The chemicals used in mixing the hardener are never added directly to the hypo solution.

Alum.—Alum is a white powder, a chemical combination of the sulphates of either sodium, potassium or ammonium, and sulphate of aluminum. Alum hardens the gelatine emulsion and in warm weather tends to keep the emulsion from blistering or frilling.

Acetic Acid.—Acetic acid is used to stop the development immediately by neutralizing the alkali of the developer in the small amount of developer adhering to the surface or absorbed in the emulsion of the plate or print when transferred to the fixing bath.

In neutralizing the alkali, "developer stains" are also obviated, especially on prints. Aside from this purpose the acetic acid performs a function in cases where the amount of the sulphite of soda in a developer for plates is reduced in order to obtain "stained negatives" of pronounced yellow color. The acetic acid in the fixing bath in such cases will control the amount of such color.

Acetic acid comes in solutions of various strengths. Photographic formulas usually call for a 28 per cent solution known as No. 8.

Sodium Sulphite.—Sodium sulphite is used in the acid hardener for the same purpose for which it is used in a developer, to prevent the oxidation of the small quantity of the developer carried over to the fixing bath on or in the plate or print. The sulphite also protects the hypo from being decomposed by the acid and alum.

Chrome Alum Fixing Bath.—This bath may be used at a higher temperature and has greater hardening properties than the one containing white alum. In making a solution chrome alum is substituted for white alum so that the bath contains chrome alum, sulphite of soda, hypo and acetic acid. Owing to the presence of

chrome alum this bath instead of being colorless is dark green. It is used only for negatives and never for prints.

Chrome Alum.—Chrome alum has a greater hardening action on the emulsion than white alum and thus enables the emulsion to withstand wash water or solution at higher temperatures. Chrome alum is the same as alum except that the sulphate of aluminum is replaced by chromium sulphate. It comes on the market in bluish-violet crystals which should be pulverized in a mortar to expedite solution.

Formalin Fixing Bath.—Another fixing bath which can be successfully used at even higher temperatures than those at which it is safe to use chrome alum is the formalin fixing bath. With this bath the temperatures may be as high as 95 deg. F. without causing trouble. The bath is composed of a solution of hypo, formalin and sulphite of soda.

Formalin.—Formalin, like ammonia, is a colorless solution of gas in water, the gas in this case being formaldehyde. Formalin is a trade name for a 40 per cent aqueous solution of the gas.

OTHER CHEMICALS USED IN AERIAL PHOTOGRAPHY

Citric Acid.—Citric acid is used in developers for motion picture film. It may also be used instead of acetic acid in fixing bath hardeners, although not so successfully.

Potassium Bichromate.—Potassium bichromate comes in orange-red crystals. It is fairly soluble in water. It forms a yellow-colored solution. The chemical is very poisonous when taken internally and to prevent death the patient should be given an emetic at once and the stomach pump used. It is absorbed by the skin and in some cases gives rise to ulcers all over the body and particularly on the hands and arms. It is used in a tray-cleaning solution.

Mercuric Chloride.—Mercuric chloride comes in white crystals and is used for the intensification of negatives. This substance, known also as corrosive sublimate, is extremely poisonous and must be handled with great care. If it is in a highly concentrated solution it will injure the hands. It is not readily soluble in water and, therefore, in making a solution care must be taken to see that it is thoroughly dissolved.

Potassium Ferricyanide.—Potassium ferricyanide is used in Farmer's reducer. It comes in yellow crystals and is poisonous if taken internally and must be very carefully handled.

Potassium Permanganate.—Potassium permanganate is used in the proportional reducer for negatives, which will be explained later. It comes in the form of violet-colored crystals and is easily dissolved, a single crystal being sufficient to turn quite an appreciable quantity of water purple. It is also used to remove pyro stains from the hands.

Ammonium Persulphate.—Ammonium persulphate is used in the selective reducers for negatives. It is a white, crystalline salt. It absorbs water very rapidly and therefore should be kept as much as possible in tightly corked bottles.

Sodium Sulphide.—For the best photographic results this chemical should be in the form of white crystals. If the crystals are colored the chemical is impure and it is best not to use it. It is used as the redeveloper when obtaining a sepia tone on bromide paper by the redevelopment process.

Gum Arabic.—Gum arabic is used to make one of the adhesives employed in mounting the photographs composing a mosaic. It comes in the form of hard, globular lumps and dissolves very slowly in water. When solutions of it are desired it is best to mix the gum and water together a few days in advance of when the solution is needed. The solution is expedited if the gum is suspended in a cheese-cloth bag from a large-mouthed jar or bottle. A plain solution of gum and water will sour quickly. To prevent this a few grains of salicylic acid, about one grain for each ounce of water, should first be dissolved in the water.

Glycerine.—Glycerine is added to the gum arabic solution used as an adhesive in mosaic making to give the solution more viscosity and to make it dry more slowly. This is desirable when pasting down the individual photographs composing a mosaic so that each may be moved around into proper adjustment. Glycerine is a thick, viscid liquid of the alcohol group.

Sulphuric Acid.—Sulphuric acid is used in reducers and in tray-cleaning solutions. The solution will destroy animal tissue if concentrated and will eat the tables or floor upon which it may fall. It should be handled very carefully and should be kept in a glass-stoppered bottle.

RULES FOR MIXING CHEMICALS

1. *Use the purest form of water readily obtainable.*

2. *Dissolve the preservative first.*—In the case of metol dissolve only a portion of the sulphite first. Dissolve the metol and then add the remainder of the sulphite.

3. *Be sure that one chemical is thoroughly dissolved before adding the next.*—If the alkali is added before the crystals of the developing agent are dissolved each crystal becomes oxidized at the surface and the resulting solution will give fog.

4. *Mix the developer at as low a temperature as possible.*—No definite gradation of temperature can be predetermined since certain chemicals do not dissolve well unless the solution has been heated.

5. In the case of desiccated chemicals like sodium carbonate or sodium sulphite, *add the chemicals to the water* slowly while stirring rapidly.

WEIGHTS AND MEASURES

In photographic work it is essential to know how to prepare properly and accurately the requisite solutions. Success depends upon solutions composed of ingredients that have been accurately measured or weighed and properly mixed. In order to compound formulas accurately it is necessary to use various weights and measures.

Systems of Weights and Measures.—The British system of weights and measures is established by law in this country, but the use of the metric system by scientists is quite common, if not universal, and familiarity with this system is desirable. In photographic work the avoirdupois table is used in weighing solids and the fluid measures for liquids:

$27\frac{1}{2}$ grains (gr.)	= 1 dram or drachm (drm.)
16 drams (drm)	= 1 ounce (oz.), 440 gr.
16 ounces (oz.)	= 1 pound (lb.), 7,000 gr.

For the purpose of compounding photographic formulas the following table, while not mathematically correct, is sufficiently accurate:

1 oz. = 440 gr.	$\frac{1}{2}$ oz. = 220 gr.
$\frac{1}{4}$ oz. = 110 gr.	$\frac{3}{4}$ oz. = 330 gr.

Scales in Use.—There are two standard size scales used in the photographic laboratory. The smaller is a studio scale with weights ranging from one grain to two ounces, and the larger scale, with weights ranging from one-quarter ounce to two pounds. The smaller scale has a sliding weight on a beam graduated in grains from 0 to 50 and similarly measured off in corresponding metric weights and the following brass weights:

50 grains (two weights)
$\frac{1}{4}$ ounce
$\frac{1}{2}$ ounce
1 ounce
2 ounces

and the corresponding metric weights.

This scale is used for weighing out small quantities of a substance and is consequently of delicate construction. Great care should be exercised in handling these scales as the knife-edges of the fulcrums can easily be damaged and cause inaccuracy in the weighing. This scale is of an equal-arm-balance type with two round flat balance pans. When weighing, the weight should be placed on the right-hand pan and the material to be weighed on the left pan. It is always best when weighing chemicals to place a piece of paper on each pan, being careful to see that the paper is of the same size and kind; and also to weigh each chemical on a separate piece of paper.

Weighing Solids.—When weighing a substance, place the pieces of paper of equal size and kind on the pans and upon the right-hand pan place weights corresponding to the amount of chemical desired. Then hold the container in the right hand and pour the material slowly on the paper on the left-hand pan. As it approaches the point of balance tap the left pan lightly so as not to overpour the amount desired. If this should happen do not use the finger to remove the excess, but take a small piece of paper, fold it through the middle and use it as a spoon. Add or subtract from the material in the pan until the pointer shows that the pans are in perfect balance. The same methods apply to the use of the larger scale, which, although not so delicate as the smaller scale, should be used carefully. When cleaning a scale never use a strong acid or sandpaper to remove corrosion as this may cause inaccuracy.

Weighing a Liquid.—To weigh a liquid first place the vessel in which the liquid is to be weighed on the left-hand pan of the scales and balance it perfectly with extra weights on the right-hand pan or any small objects which are at hand. Then place the weights, equivalent to the amount of liquid desired, on the right-hand pan. Pour the liquid slowly into the vessel on the left-hand pan and at the same time tap the left-hand pan gently so as not to overpour the amount desired. Add or subtract until the point of balance is reached.

60 minims	(min.)	= 1 dram or drachm (drm.)
8 drams	(drm.)	= 1 fluid ounce (oz. = 480 min.)
16 ounces	(oz.)	= 1 pint (pt.)
2 pints	(pt.)	= 1 quart (qt.) = 32 fluid ounces
4 quarts	(qt.)	= 1 gallon (gal.) = 128 fluid ounces.

By this table, water and other liquids are measured in standard sized containers some of which are called graduates.

Graduates.—The following sizes of graduates are the most commonly used:

32-ounce—graduated in ounces and pints.
16-ounce—graduated in ounces.
8-ounce—graduated in ounces and half ounces.
4-ounce—graduated in ounces, the first ounce graduated in drams.
1-ounce—graduated in drams and minims.

Practically, the only sizes used in the darkroom are the 32- and 16-oz. graduates.

Very few formulas call for amounts of liquids less than one ounce and it is practically never necessary to measure less than a dram. One minim is approximately equal to one drop. Use as many drops, therefore, as the formula calls for in minims. When measuring liquids, especially acids, always use great care in pouring from the bottle. Hold the bottle firmly in the right hand and the graduate in the left, holding the bottle on a level with the eyes while pouring.

The Metric System.—The metric system possesses the following advantages:

1. Decimal relation.
2. Extremely simple relation of the units of length, area, volume, and weight, to one another.
3. Uniform and self-defined names of the units.

These advantages prove it to be most practical. The fundamental unit of the metric system is the meter, which is the unit of length. From this the units of capacity (liter) and of weight (gram) are derived. All other units are either decimal subdivisions or multiples of these units. For all practical purposes one cubic decimeter equals one liter and one liter of water (under certain conditions) weighs one kilogram. The metric tables are formed by combining the words "meter," "gram" and "liter" with six numerical prefixes:

Milli	= one thousandth,	1/000	.001
Centi	= one hundredth,	1/100	.01
Deci	= one tenth,	1/10	.1
Unit	= one,	1	
Deca	= ten,	10	
Hecto	= one hundred,	100	
Kilo	= one thousand,	1000	

Thus one kilometer, kilogram, kiloliter is equal to 1,000 meters or grams, or liters. The square and the cubic units are the squares and the cubes of the linear units. The following tables are the correct equivalents with our system of weights and measures:

Capacity:

1 milliliter	=	0.0338	oz. liquid
1 liter	=	1.057	qt. liquid
1 ounce liquid	=	29.57	milliliters
1 quart liquid	=	0.946	liter

Weight:

1 gram	=	15.43	grains, 0.0353 avoirdupois ounce
1 kilogram	=	2.205	avoirdupois pounds
1 grain	=	0.0648	gram
1 avoirdupois ounce	=	28.35	grams
1 avoirdupois pound	=	0.4536	kilogram

Rules for Conversion.—To convert inches to centimeters; multiply by 2.54 (approximately multiply by 5 and divide by 2).

Centimeters to inches: divide by 2.54 (approximately multiply by 2 and divide by 5).

Millimeters to inches; divide by 25.4 (approximately multiply by 4 and divide by 100).

Fluid ounces to cubic centimeters; multiply by 29.6.

Cubic centimeters to fluid ounces; divide by 29.6.

Grains to grams; divide by 15.43.
Ounces, avoirdupois, to grams; multiply to 28.4.
Grams to ounces, avoirdupois, divide by 28.4.

Per Cent Solutions.—For certain purposes it may be necessary to use solutions of certain strength, these solutions being known as per cent solutions.

The ounce avoirdupois contains $437\frac{1}{2}$ grains. The fluid ounce contains 480 minims. Therefore, in making a 10 per cent solution the ounce avoirdupois must be dissolved in enough water to make a solution containing 1 grain in 10 minims, that is to say, 4.375 minims or practically $9\frac{1}{8}$ fluid ounces is the proper quantity of liquid to dissolve 1 ounce avoirdupois. To determine the number of grains per fluid in the per cent solution multiply the percentage figure by 4 and add to the result its tenth part. Thus, for a 5 per cent solution, 5 times 4 plus 1/10 (5 times 4 equals 20 plus 2) equals 22 grains per fluid ounce of water.

Using the metric system it is quite simple to make a solution of definite percentage. A 10 per cent solution is such that 100 cc. of the solution contain 10 grams of the solid. In making up the solution therefore dissolve 10 grams of the solid in less than 100 cc. of the solvent and when dissolved make up to 100 cc.

Acetic acid is made in various strengths. The No. 8 of commercial grade contains 25 to 28 per cent acid, the redistilled, 80 per cent and the glacial may come as high as 99 per cent. The different strengths may be substituted for one another if their relative acidities are taken into account. To determine the amount of one to be substituted for another, multiply the per cent of the acid called for in the formula by the number of ounces called for and divide by the per cent of the acid to be substituted. This method of calculation is applicable to any kind of solution.

Hydrometer.—The hydrometer is an instrument which registers the specific gravity of liquids, which is the relative weight of those liquids in comparison with the relative weight of an equal volume of pure water.

CHEMISTRY OF FIXATION

After development, film or plates and prints are placed in a solution called a fixing bath, which removes the undeveloped silver-bromide from them.

In the process of fixing, the silver-bromide is dissolved in the hypo.

Dissolving the Hypo.—When hypo crystals are dissolved in cold water, the solution becomes much cooler so that it is quicker to start with warm water and this is recommended.

Strength of Solution of Hypo.—For fixing, use a 35 per cent solution of hypo. This strength has been found to be best, as the fixing is accomplished by the solution entering the pores of the emulsion.

Acid Fixing Bath.—With this 35 per cent solution of hypo use an acid hardener, composed of alum, acetic acid, sodium sulphite and water. In mixing this hardener, the alum should be dissolved in warm water and then the acid added and finally the sulphite. If the sulphite is added after the alum, and before the acid, a white precipitate is formed which only with difficulty will be redissolved by the addition of the acid.

This acid fixing bath is made by taking 20 parts of plain hypo and adding to it 1 part of acid hardener.

Reason for Using Acid Fixing Bath.—Plain hypo will fix the emulsion, but the acid fixing bath does several things at the same time, whereas the plain hypo accomplishes one purpose—fixing the emulsion.

With the use of acid hardener in the fixing bath, the following takes place:

1. While the print is fixing, it is at the same time being hardened by the alum. Alum hardens the gelatine and raises the melting point.
2. The acetic acid stops development immediately by neutralizing the carbonate in the developer carried over on the prints. If a plain hypo solution is used for fixing prints, development still continues for a certain time after placing in the fixing bath, particularly if concentrated developer has been used, so that over-development is possible; while uneven development will take place and stains will result if the print is not put in motion.
3. The sulphite acts as a preservative just as in a developer but in two ways:
   (*a*) It prevents oxidation of the developer carried over to the fixing bath by the prints, which would otherwise oxidize, turn brown, and cause stains.

(*b*) It preserves or protects the hypo from the acid and the alum. If the solution of acid or alum is added to a hypo solution, a milky precipitate of sulphur is formed, but not in the presence of sodium sulphite because any sulphur which may be formed again combines with the sulphite to form hypo.

Milkiness in Fixing Bath.—A solution of plain hypo rarely turns milky unless alum or acid is added to it. Milkiness of the acid fixing bath may be due to two causes:

1. Sulphurization or the formation of sulphur in the bath. This form of milkiness may be readily distinguished because the sulphur does not settle out on standing. The milkiness may be due to one or other of the following causes:
   (*a*) Adding the hardener before all the hypo is dissolved.
   (*b*) The use of too much hardener.
   (*c*) Too much acid in the hardener.
   (*d*) The use of too little sulphite or impure sulphite.
   (*e*) High temperature. Trouble in this respect will be met with in very hot weather.

   The hypo containing acid hardener will keep but a few days in very hot weather and should therefore be mixed only as required. There should be stock solutions of plain hypo and of acid hardener, as they will keep indefinitely if not mixed.
2. A white sludge which settles out on standing. This is due to too little acid in the bath. If alum is added to sodium sulphite, a white sludge is formed which dissolves again in acetic acid. When the acid in the acid fixing bath is neutralized by the alkali in the developer carried over by the prints, a white sludge is likely to form in the fixing bath, due to the continued reduction in the amount of acid. The remedy is to use more hardener or use a little more acid and sulphite when mixing the hardener.

The Process of Fixing.—A plate, film or print fixes in two stages. First, the silver compound in the emulsion combines with the hypo to form a colorless compound which is comparatively insoluble, and at this point the milkiness of the plate disappears leaving visible only the developed silver of the image.

By leaving the plate or print in the bath longer, this compound is changed to a more soluble one which can be much more readily washed out by water. If the plate is removed from the fixing bath immediately after the milkiness has disappeared, which is the first stage of fixing, no amount of washing will remove the compound silver salt and this will give trouble later in two ways:

1. The silver compound will be changed to silver sulphide on exposure to the air and will cause the yellow stain of silver sulphide.
2. On drying a plate with alcohol the film will turn white. This effect is called opalescence and is noticeable also on plates or film dried too rapidly at a high temperature.

Safe Rule for Length of Fixing Time.—The only safe rule is to leave prints and negatives in the fixing bath for double the time required to remove the milkiness. The quickest way of fixing properly is to use two fixing baths, doing practically all of the fixing in the first and finishing with a new clean bath. By thorough fixing less washing will suffice.

Rate of Fixing.—The rate of fixing depends on the following:

1. Nature of the emulsion: A lantern slide or print fixes much more quickly than a fast plate or film. This depends of course upon the thickness of the emulsion as well as the chemicals used in it.
2. The strength of the hypo: A plate fixes in the shortest time in a 35 or 40 per cent solution of hypo. If the solution is stronger than this, the plate fixes more slowly, whereas in a very strong solution the plate may not fix at all, such solution, being almost like syrup, hardly penetrates the emulsion.
3. Temperature: A plate fixes more quickly in a warm solution than in a cool one. Keep the bath as nearly 65 to 70 deg. F. as possible.

Life of the Fixing Bath.—Do not overwork the fixing bath. With use the hypo becomes exhausted or saturated with silver while the acid of the acid hardener becomes neutralized by the carbonate in the developer carried over on the plates and paper. The degree of exhaustion can be judged roughly by the rapidity of fixing. If fixing becomes slow at a normal temperature, substitute a fresh bath.

Effect of Acid Fixing Bath on the Color of the Negative.—When a stained negative is wanted, use the plain hypo solution because the acid hardener which contains acid and sulphite will tend to bleach out and remove the yellow stain from the negative.

Chrome Alum Fixing Bath.—Chrome alum hypo is used to a great extent in warm weather. Even if the temperature goes up to 85 deg. F. chrome alum solution can be used because the chrome alum has greater hardening action on the emulsion than the plain alum. A chrome alum fixing bath is composed of:

Hypo
Sulphite of soda
Chrome alum
Acetic acid
Water

As this solution is prepared with hypo in it, dissolve the hypo first and then dissolve the alum, acid and then the sulphite as in the acid hardener and then mix, finally adding enough water to make the formula complete.

Chrome alum bath keeps well and is stable when slightly acid. If the alkali exceeds a certain amount, by the addition of an excess of carbonate carried over from the developer, a green sludge will precipitate which renders the bath useless and it should be thrown away.

The plates should be well rinsed though not too long, before being placed in the bath.

The quantity of acid present is calculated to compensate for some of the carbonate carried over, although no more acid can be used, since, if too much is present, blisters will form on the negatives.

Chrome Alum Metabisulphite Bath.—Another solution sometimes used at a temperature up to 85 deg. is the chrome alum metabisulphite solution in which metabisulphite is substituted for the sodium sulphite of the chrome alum bath and acid is omitted.

Fixing Bath Used at Temperatures from 85 *to* 95 *Deg. F.*—When the temperature ranges from 85 to 95 deg. F. formalin fixing bath should be used which is composed of:

Hypo
Sodium sulphite
Formalin
Water

This is made by first dissolving the hypo, then the sulphite and finally adding the formalin. On account of the fumes, it should be kept in a closed container. It keeps well, and although a milky precipitate may form it will do no harm.

Mixing Fixing Baths.—

Plain Hypo:

Hypo		5 oz.
Water (about 125 degrees F.)	To	16 oz.

Acid Hardener:

Sodium sulphite, desiccated		$1\frac{1}{4}$ oz.
Acetic acid, 28 per cent solution		$6\frac{1}{2}$ oz.
Alum		385 gr.
Water	To	16 oz.

The correct method is as follows:

1. Take about one-half of the total amount of water which will be used. This water should be warm.
2. Dissolve the sulphite in this water.
3. Add the acid and stir the solution.
4. Dissolve the alum.

Never add the alum before the acid is put in the solution.

Acid Hypo:

Plain hypo solution	20 oz.
Acid hardener	1 oz.

Chrome Alum Hypo:

Hypo		7 oz.
Sodium sulphite		1 oz. 175 gr.
Chrome alum		2 oz. 350 gr.
Acetic acid		7% solution, 1 oz.
Water	To	32 oz.

The correct method for mixing the above solution is:

1. Dissolve the hypo crystals in about 10 oz. of warm water.
2. In another container having about 10 oz. of warm water dissolve the alum and then the sulphite.
3. Pour the alum-sulphite solution into the hypo solution while stirring the latter.
4. Next add the acetic acid.
5. Add water to 32 oz,

Formalin Hypo:

Hypo		$4\frac{1}{2}$ oz.
Sodium sulphite	To	393 gr.
Formalin		2 oz.
Water	To	16 oz.

Dissolve the chemicals in the order named.

CHEMISTRY OF WASHING, TONING, REDUCTION AND INTENSIFICATION

Object of Washing.—The object of washing negatives or prints is to remove from them the chemicals they have absorbed in the fixing bath. It should not be necessary to wash out silver compounds, but only the chemicals of the fixing bath. If, however, an exhausted fixing bath is used, silver compounds will be present during washing and must be completely removed. This is important in case that work has to be hurried and the time of washing cut down, when it is most important that fixing should be complete.

As stated before, the best way of insuring complete fixing is to use two fixing baths and to transfer the negatives or prints to the second bath after they have been fixed in the first. Then, when the first bath begins to show signs of exhaustion and refuses to fix quickly, it should be replaced by the second, and a new clean working fixing bath should be used in the place of the second bath. This procedure insures that no material can be removed from the fixing bath until the first insoluble compound of silver and hyposulphite has been converted into the second soluble compound. It must be remembered that this insoluble compound is invisible and that if a negative is transferred to the washing tank as soon as it is visibly clear, some of the insoluble silver-hypo compound will remain in the negative when it is dry. If the negative is transferred to a second fixing bath instead of the washing tank, this compound will be entirely removed and the task of washing will be much simplified and the time necessary for complete fixation shortened.

Diffusion.—The rate of washing depends entirely upon the diffusion of the hypo out of the emulsion into the water. This diffusion rate has nothing to do with solubility. The solubility of a substance fixes the proportion of the substance which can go into solution.

Same Speed of Washing in Warm as in Cold Water.—Although it is true that any salt will diffuse more rapidly in warm water than in cold, nevertheless when washing a photographic negative or print the diffusion has to take place in gelatine and the warmer the water in which the gelatine is placed, the more its swelling hinders diffusion in about the same proportion as the rise in temperature accelerates it. Thus, as a matter of fact, washing goes on at about the same rate at all ordinary temperatures.

Effect of Acid Hardener in Fixing Bath.—Gelatine is like a sponge; the effect of hardening it is to contract all the network of the sponge, but in so doing the gelatine as a whole is not contracted and there is no difference in the diffusion between gelatine which has not been hardened and that which has been hardened, unless the gelatine has been dried after hardening. If a negative is thoroughly hardened in the fixing bath and then dried it will not expand much when soaked again; consequently diffusion through it will be difficult, but before drying the hardening does not affect diffusion and the materials which wash most quickly are those in which the gelatine has not been swollen in its treatment, either in development or fixation, but has been kept in a firm solid condition.

Rate of Washing.—The actual rate of washing may be understood by remembering that the amount of hypo remaining in the gelatine is continually halved in the same period of time as the washing process. An average negative, for instance, will give up half its hypo in two minutes, so that at the end of two minutes half the hypo will be remaining in it, after four minutes, one-quarter, after six minutes, one-eighth, after eight minutes, one-sixteenth, ten minutes, one thirty-second, and so on. It will be seen that in a short time the amount of hypo remaining will be infinitesimal. This, however, assumes that the negative is continually exposed to fresh water, which is the most important matter in arranging the washing of either negatives or prints.

Manner of Washing.—If a number of prints are put in a tray and water is allowed to splash on the top of the tray, it is very easy for the water on the top to run off again, and for the prints at the bottom to lie soaking in a pool of fairly strong hypo solution, which is much heavier than water and which will fall to the bottom of the tray. If the object is to get the quickest washing, washing tanks should be arranged so that the water is continuously and com-

pletely changed and the prints or negatives are subjected to a continuous current of fresh water. If water is of value and it is desired to economize in its use, then by far the most effective way of washing is to use successive changes of small quantities of water, putting the prints first in one tray, leaving them there for from two to five minutes, and then transferring them to an entirely fresh lot of water, repeating this until they are washed.

Best Method for Washing.—If the prints can be placed in a tank which has an inlet of fresh water at the top and a siphon arrangement to take the water from the bottom at the side of the tank opposite to the inlet, the prints will receive fresh water at all times. Water containing hypo is heavy and will settle to the bottom. It is necessary to remove the water from the bottom and allow the fresh water to come in from the top.

Test for Complete Washing.—The progress of the washing can be followed by using a weak solution of potassium permanganate. Take a print out of the wash and allow a little of the water to drip into this solution. If hypo is present the water will change in color from a light purple to a yellowish brown. If the prints have washed sufficiently there will be no change in color.

Or, place a corner of one of the prints to the tongue and if hypo is present it can be detected by the taste. (But this test is not so sensitive as the permanganate test.) Six changes of water leaving the prints for five minutes each should be sufficient to eliminate the hypo effectively from any ordinary material.

Chemical Reduction.—It is unfortunate that the word "reduction" is used in English for this process. In other languages the word "weakening" is used, and this is a better word as the chemical action involved in the removal of silver from a negative is oxidation, and the use of the word "reduction" leads to confusion with true chemical reduction, such as occurs in development.

Kinds of Reducers.—Photographic reducers are oxidizing agents, and almost any strong oxidizing agent will act as a photographic reducer and will remove silver, but various oxidizing agents behave differently in respect to the highlights and shadows of the image. Reducing solutions can be classified in three groups:

1. Subtractive reducer.
2. Proportional reducer.
3. Selective reducer.

Subtractive Reducer.—The subtractive reducers remove an equal amount of silver from all parts of the image and consequently remove the detail from the shadows along with an equal amount of the deposits forming the highlights of the negative. The typical subtractive reducer is that known as *Farmer's reducer,* consisting of a mixture of potassium ferricyanide and hypo, the potassium ferricyanide oxidizing the silver to silver ferricyanide and the hypo dissolving the latter compound. Farmer's reducer will not keep when mixed, but decomposes rapidly, so that it is usually prepared by making a strong solution of the ferricyanide and then adding a few drops of this to a hypo solution when ready to use the reducer. It is especially useful for cleaning negatives or lantern slides which show slight fog, and is also used for local reduction, the solution being applied with a brush or a wad of absorbent cotton.

Proportional Reducer.—Proportional reducers are those which act on all parts of the negative in proportion to the amount of silver present there. They undo the action of development since during development the density of all parts of the negative increases proportionally. A correctly exposed but overdeveloped negative should be reduced with a proportional reducer. In this way the density is reduced but the detail maintained. This is done by means of potassium permanganate and sulphuric acid. In this reducer a negative which has been soaked in water is reduced evenly whereas a negative placed in it when dry will receive greater reduction in the highlights.

Selective Reducers.—In order to have a selective reducer, one is required which acts more on the heavy deposits of the negative and which will reduce the highlights without affecting the detail in the shadows. Only one such reducer is known and this is ammonium persulphate. Ammonium persulphate is a powerful oxidizing agent and attacks the silver of the negative, transforming it into silver sulphate, which dissolves in the solution. It must be used in an acid solution and is somewhat uncertain in its behavior, occasionally refusing to act, and always acting more rapidly as the reduction progresses.

The plate must be carefully watched and withdrawn as soon as action is detected in the weaker spots.

Intensification.—Instead of reducing or removing the silver, forming the image in a negative, intensification consists in building up or adding an opaque substance to the image.

Generally speaking, all methods produce the same effect, but they vary in degree, that is, they increase contrast.

A negative to be intensified must have been thoroughly fixed. Thorough washing after fixing is desirable. If a negative is dry, it should be soaked in water before intensification is attempted. The negative should be bleached in a solution containing mercuric chloride, potassium bromide and water.

When bleached, it is washed for half an nour and then blackened thoroughly in a freshly prepared solution of sodium sulphite and water. Then wash and dry. The process may be repeated so as to produce any increase of strength desired.

Intensification cannot add detail to a negative. If detail has not been obtained in the negative by proper exposure intensification cannot put it there.

Table of Treatment for Poor Negatives:

Nature of Negative	*Treatment*
1. Underexposed and underdeveloped	Intensify
2. Underexposed and normally developed	Do not attempt to improve it
3. Underexposed and overdeveloped	Reduce with persulphate
4. Normally exposed and underdeveloped	Intensify
5. Normally exposed and overdeveloped	Proportional reducer
6. Overexposed and underdeveloped	Intensify, then use Farmer's Reducer
7. Overexposed and normally developed	Use Farmer's Reducer
8. Overexposed and overdeveloped	Use Farmer's Reducer

DEVELOPING MATERIALS

Sepia Toning Solution:

Solution "A" (bleaching solution):

Potassium ferricyanide		150 gr.
Potassium bromide		150 gr.
Water	To	16 oz.

Solution "B" (redeveloper):

Sodium sulphide		90 gr.
Water	To	20 oz.

Intensifier:

Solution "A":

Potassium bromide		187 gr.
Mercuric chloride		187 gr.
Water	To	16 oz.

Solution "B":

Sodium sulphite, 10 per cent solution		1 oz.
Water	To	10 oz.

Subtractive Reducer:

Solution "A":

Potassium ferricyanide		½ oz.
Water	To	10 oz.

Solution "B" (freshly made):

Hypo		1 oz.
Water	To	5 oz.

Working solution; when ready to begin reduction add enough A to B to give a yellow color.

Proportional Reducer:

Solution "A":

Potassium permanganate		10 gr.
Water	To	5 oz.

Solution "B":

Sulphuric acid		50 minims
Water	To	5 oz.

For use, take one ounce of "A" and two ounces of "B" and water to 10 ounces.

Selective Reducer:

Ammonium persulphate		1 oz.
Sulphuric acid		⅓ oz.
Water	To	32 oz.

Fixing Baths

Plain Hypo:

35 per cent solution of hypo, as follows:

Hypo		16 oz.
Water	To	64 oz.

Acid Hardener:

Sodium sulphite	48 oz., or 12 lb.
Acetic acid, 28 per cent	144 oz., or $4\frac{1}{2}$ gal.
Alum (powdered)	48 oz., or 12 lb.
Water . . . To	384 oz., or 12 gal.

NOTE: During extreme cold months, reduce the amount of alum about 50 per cent.

Acid Fixing Bath:

Plain hypo solution	20 parts
Acid hardener solution	1 part
(Use full strength.)	

Chrome Alum Fixing Bath:

Water	$6\frac{1}{4}$ gal.
Hypo	20 lb.
When dissolved add:	
Water	100 oz.
Sodium metabisulphite	30 oz.
Chrome alum	8 oz.
Water . . . To	10 gal.

Formalin Fixing Bath:

Hypo	9 oz.
Sodium sulphite	1 oz., 350 gr.
Formalin (40 per cent formaldehyde solution)	$4\frac{1}{4}$ oz.
Water . . . To	32 oz.

To Remove Pyro Stain from Hands

A:	Water	6 oz.
	Potassium permanganate	1 oz.
B:	Water	4 oz.
	Sodium sulphite, 60 per cent solution	4 oz.
	Acetic acid	4 oz.

For use: Wash hands first in A and then in B.

Tray Cleaner:

Potassium bichromate	4 oz.
Sulphuric acid	8 oz.
Water . . . To	32 oz.

Adhesive:

Water	1 pt.
Gum arabic	1 lb.
Glycerine	2 oz.

Intensifiers

Mercury

A: Potassium bromide .... 375 gr.
Mercuric chloride .... 375 gr.
Water .... To 32 oz.
Bleach in above solution.

B: Sodium sulphite .... 1 per cent solution
Redevelop in B for normal contrast.

C: Ammonia .... 1 per cent solution
Redevelop in C for better contrast.

D: Potassium cyanide .... 300 gr.
Silver nitrate .... 375 gr.
Water .... To 32 oz.
Redevelop in D for extreme contrast.

NOTE: In making up D dissolve the Potassium Cyanide and Silver Nitrate separately and add the latter to the former until a permanent precipitate is just produced; allow the mixture to stand a short time and then filter.

Sepia Toning Solution

Bleaching Solution:

Potassium ferricyanide	300 gr.
Potassium bromide	300 gr.
Water	To 32 oz.

Wash.

Redeveloping Solution:

Sodium sulphide .... 1 per cent solution

Wash.

NOTE: This formula can also be used for intensification of negative.

Reducers

Farmer's Reducer (Cutting):

Add enough Potassium Ferricyanide to a plain hypo solution (generally a 1 to 4 solution of hypo) to make it a lemon color.

After reducing, wash thoroughly and place in plain hypo solution.

Permanganate Reducer (Cutting):

A:	Potassium permanganate		1 oz.
	Water	To	20 oz.
B:	Sulphuric acid		1 oz.
	Water	To	20 oz.

For use: 1 oz. A, 2 oz. B, 64 oz. water.

After reducing place negative in plain hypo or acid hypo to remove stain, then wash thoroughly.

Persulphate Reducer (Flattening):

Ammonium persulphate		1 oz.
Sulphuric acid		$\frac{1}{3}$ oz.
Water	To	32 oz.

Use full strength.

After reducing, place in acid fixing bath for a few minutes, then wash thoroughly.

Proportional Reducer:

Use equal amounts of permanganate and persulphate reducers.

Pyro-Metol Developer for Plates and Film

Solution A:

Potassium metabisulphite		1 oz.
Metol		$\frac{1}{4}$ oz.
Pyrogallic acid		2 oz.
Potassium bromide		$\frac{1}{2}$ oz.
Water	To	24 oz.

Solution B:

Sodium sulphite		1 oz.
Water	To	24 oz.

Solution C:

Sodium carbonate		3 oz.
Water	To	24 oz.

For use:	Solution A	1 part
	Solution B	1 part
	Solution C	1 part
	Water	4 parts

Developer for Paper and Lantern Slides:

Sodium sulphite	$2\frac{1}{2}$ oz.
Metol	75 gr.
Hydroquinone	300 gr.
Sodium carbonate	$3\frac{1}{2}$ oz.
Potassium bromide	40 gr.
Water ... To	32 oz.
When cool add Alcohol (in winter months)	4 oz.

Dissolve about $\frac{3}{4}$ of sulphite after No. 2 and No. 3 are dissolved.

For Use:

Bromide paper—One part solution to six parts water.

Azo and velox—One part solution to four parts water.

Lantern slides—One part solution to six parts water, and for each ounce of solution used, add one drop of potassium bromide.

Developer for Process Film and Process Plates:

Solution A:

Sodium metabisulphite	$3\frac{1}{4}$ oz.
Hydroquinone	$3\frac{1}{4}$ oz.
Potassium bromide	$3\frac{1}{4}$ oz.
Water ... To	130 oz.

Solution B:

Sodium hydroxide	6 oz.
Water ... To	1 gal.

For use: Solution A .... 1 part
Solution B .... 1 part

Normal development: 3 minutes at 65 deg. F.

1st Dissolve part of the sulphite.
2nd Dissolve Hydroquinone.
3rd Dissolve rest of sulphite, then bromide.

Developer for Orthochromatic Film When Developed in Tank:

Potassium metabisulphite	12 oz.
Sodium sulphite	4 lb.
Metol	4 oz.
Pyrogallic acid	2 lb.
Sodium carbonate	6 lb.
Potassium bromide	6 oz.
Water to bottom of top rivets	19 gal.

Dissolve all chemicals in the order named, in a cheese-cloth screen suspended in water, except in the case of the sulphite. Dissolve a portion

of the sulphite before the metol, and the remainder after the pyrogallic acid.

See that each chemical is thoroughly dissolved before adding another.

Develop for 20 minutes at 60 deg. F.

NOTE: If a stained negative is desired reduce the amount of sodium sulphite to 1 lb.

Developer for Hypersensitized Panchromatic Film:

Metol	4 oz.
Potassium metabisulphite	12 oz.
Sodium sulphite (desiccated)	2 lb.
Sodium carbonate (monohydrated)	6 lb.
Potassium bromide	12 oz.
Pyrogallic acid	2 lb.
Water, distilled	19 gal.

Develop for twenty minutes at 58 deg. F.

If plain panchromatic film is to be developed, reduce the amount of potassium bromide to 8 oz.

NOTE: Mix in this order:

1 Water
2 Metabisulphite
3 Small part of sulphite
4 Metol
5 Pyrogallic acid
6 Balance of sulphite
7 Carbonate
8 Bromide

Metol-Hydroquinone (Contact Printing Paper)

Stock Solution:

Metol (or elon)		25 gr.
Sodium sulphite (desiccated)		350 gr.
Hydroquinone		36 gr.
Sodium carbonate (monohydrated)		260 gr.
Potassium bromide (granular)		8 gr.
Water	To	16 oz.

For use: Stock solution.......... 1 part
Water.................. 2 parts

Two High-Temperature Developers for Hyper-Sensitized Panchromatic Aerial Film:

1. Potassium metabisulphite	3 oz.
Sodium sulphite	$1\frac{1}{2}$ lb.
Sodium carbonate (monohydrated)	$1\frac{1}{2}$ lb.
Potassium bromide	1 oz.
Pyrogallic acid	1 lb.
Water	18 gal.

At 82 deg. F. Time of development 4 minutes.

2.	Paramidophenol hydrochloride	1	lb.
	Sodium sulphite (desiccated)	5	lb.
	Sodium carbonate (monohydrated)	10	lb.
	Water ... To	19	gal.

At 85 deg. F. Development 8 minutes.

DEVELOPING PROCESS

Developer Troubles. —

1. If a developing solution is colored (usually brown) it is very probable that the solution has become oxidized and will not develop properly, giving stain and fog. This is due to too much carbonate or too little sulphite.
2. If a developing solution, when poured on an exposed plate or paper, does not develop the image in a reasonable time at a normal temperature the solution has been incorrectly mixed. The causes of this trouble may be too little or no developing agent, or carbonate, or too much bromide.
3. If the solution gives fog, the trouble may be attributed to any of the following causes:
   a. A too energetic developer even if fresh and correctly mixed may give fog. Some emulsions need more energetic developers than others, and that is why the developer should be adjusted to the emulsion.
   b. A developer may be made more energetic by increasing the concentration and raising the temperature, or by adding more carbonate, although it is then likely to give fog. That is why a developer should not be used stronger than recommended or at a temperature higher than 65 to 70 deg. F.
   c. Oxidation products of the developer generally cause fog. It is important to prevent the oxidation as far as possible by using sufficient sulphite (which should be pure) and using water free from air when mixing the developer.
   d. Care should be taken to prevent any undue oxidation when mixing the developer. Never add the carbonate to the reducing agent before adding sulphite and do not unnecessarily warm the developer.
   e. Old developer which has turned brown by continued use,

prolonged exposure to the air, or owing to the presence of too much alkali or too little sulphite will give fog.

f. The presence of salts of metals such as copper, brass and tin in the developer should be avoided. A salt of copper, if present in a developer only to the extent of 1 part in 10,000, will produce fog on certain emulsions immediately.

g. The addition of small amounts of potassium bromide to a developer is usually a sufficient protection against chemical fog. That is why most developers contain a little bromide.

Temperature of the Developer.—The temperature has much to do with the development—especially when using M. Q. In such developers the hydroquinone becomes inert at 40 deg. F. The hydroquinone is used to give density and contrast; and if the developer is too cold the hydroquinone does not do its part and the result is that if one is developing plates one often obtains good detail but negatives so thin that they are unprintable.

Practical Suggestions for Handling Photographic Chemicals.—The chemicals may have been weakened or may have deteriorated in some way from standing on the shelves or having the corks left out of the bottles, or for some similar reason. For instance, hydroquinone, metol and pyro will darken with age if allowed to stand in either uncorked bottles or uncolored bottles. Light and moisture produce this effect. Sodium hydroxide when exposed to air draws moisture from it and a white opaque crust will form on the outer portion of the stick. This has weakened the hydroxide to such an extent that it will not perform its part in the formula. In case any sticks have this white crust upon them, scrape it off carefully and use the good portion of the hydroxide in the formula.

Oxidation.—Sodium sulphite when exposed to the air is converted into sodium sulphate, which is useless as a preservative. Oxygen also combines with sodium and potassium bisulphite and metasulphite, and ruins them for photographic purposes. This combining of oxygen with a substance is called oxidation.

Deliquescence.—Some other chemicals combine with or take up the moisture in the air until they gradually dissolve into a solution. Sodium sulphite, sodium hydroxide and ammonium persulphate are extremely deliquescent. When storing chemicals do not store

developing agents or reducers near radiators as heat tends to increase the amount of oxidation.

Care in Handling.—In handling chemicals be careful not to spill any on the floors or tables. The solution dries and particles of chemicals will float into the air and are likely to settle upon sensitive materials, thereby ruining them for photographic purposes. In removing the stoppers or corks from bottles of chemicals do not lay them upon a table or bench, for when replaced the cork may carry some dirt with it into the chemical or even carry some other chemical back into the bottle which may neutralize the effect of the solution. When using sulphuric acid if the cork or stopper is laid down on a table it will eat a hole in the table where it was laid.

Acid into Water.—Never pour water into an acid. To dilute sulphuric acid, always pour the acid slowly into the water. Sulphuric acid will have a caustic effect if it gets upon the flesh in concentrated form and is extremely poisonous if taken internally in any amount.

Cleanliness.—In a photographic chemical room cleanliness is important to good work. Always keep trays, graduates, stirring rods, bottles, tanks, and scale trays absolutely clean at all times. Always keep chemicals in well-stoppered bottles and place them in cool, dry places. Acids should be kept in glass-stoppered bottles if possible. If not, use rubber stoppers.

CHAPTER X

DEVELOPING

By developing is meant the transformation of the silver bromide grain, after exposure to the light, into black metallic silver. A compound of metal can be separated so that the metal alone remains. Any substance that can combine with oxygen (under suitable conditions) can free a metal from its compounds. Developing agents, then, are substances which easily combine with oxygen to form oxidation products.

Rate of Development.—The rate at which the light affected silver bromide is freed from its salts depends, first, upon the rate of solution of the silver bromide and, second, upon the diffusion of the developing agent, through the gelatine, to the silver bromide grain and the removal of the oxidation products. The time occupied by diffusion is much greater than the rate of solution of the silver bromide. The amount of silver that has been produced after development has proceeded for any given length of time will depend not only upon the time of development and the developer but upon the exposure, that is, the number of grains which were affected by the light. The condition of the plate or film at any stage during development until completion will be:

1. The grains that are completely developed.
2. Developable grains which have been exposed but not as yet completely developed.
3. Underexposed grains which are not being affected by the developer.

If the plate or film is developed to its maximum the grains in numbers 1 and 2 will all be developed so that the amount of silver produced, if development is carried until it stops, represents the total number of grains of the image formed by the light before development. As the result of this progressive development of exposed grains, the contrast grows during development. If the

development is stopped at Number 1, the negative will be thin and flat. After full development there is much more density in the highlights than in the shadows where a little exposure was given, and the negative will be very contrasting. During development the exposed grains at first develop rapidly. As they begin to be used up the increase of contrast slows down until no more density or contrast can be obtained. The greatest contrast obtainable depends upon the kind of plate used. The color-sensitive plates or film used for aerial photographic work give a very high contrast when developed to the limit. Contrast does not depend upon the exposure, but upon the time of development. The amount of density obtainable does depend upon the exposure. There can be two types each of dense and thin negatives:

1. A dense negative with little contrast, appearing flat. This negative has been overexposed and normally developed.
2. A dense negative with great contrast, appearing hard. This has been normally exposed and overdeveloped.
3. A thin negative appearing flat has been fully exposed and underdeveloped.
4. A thin contrasting negative has been underexposed and overdeveloped.

Effect of Exposure.—A normally exposed negative should show a full gradation of tones. There should be no clear glass or film, even the densest shadows containing some detail. An underexposed negative has an absence of detail in the shadows, these appearing as clear glass. An overexposed negative is too dense. The shadows are full of detail while the highlights are flat and clogged.

A normally exposed plate or film is affected during development by:

1. The kind of developer (formula and age).
2. The time of development.
3. The temperature of the developer.

From the foregoing it can be seen that when developing aerial film in a tank, instructions for the developing formula, the time of development, and the temperature of the developer must be strictly followed as given.

Defects in Negatives.—Defects in negatives are sometimes due to faulty material, but in most cases all defects are due to care-

lessness and lack of cleanliness on the part of the operator. Although the causes of some defects are obvious, such as finger marks, only an experienced photographer will be able to explain at a glance the cause of many defects.

Spots.—A great many of the defects are in the nature of spots, uneven patches, or streaks which may be either black or white. A spot or patch is termed black if it is darker than the surrounding portions, and white when it is lighter. *Black Spots* may consist of actual particles of grit or foreign matter on the negative. Dust or particles or iron rust in the wash water will cling to the film during washing unless carefully wiped off. Spots of greater density than the surrounding portions consisting of silver may be produced by any of the causes which produce fog. They are usually caused by the presence of chemical dust on the film before or during development. Any undissolved particles left in the developer when mixing or any fine crystals which settle out from the developer when it is cool will settle on the plate during development and cause black spots. Always filter the developer and examine carefully to see that there are no crystals, however small, floating in it.

White Spots indicate the absence of silver and may be due to dust on the film, during either exposure or development. Dust on the film during exposure prevents the light from acting upon the emulsion beneath the particles. Because the dust is washed off during either fixing or washing, that portion of the film will remain clear. The presence of dust during development prevents the developer from reaching the emulsion. The image does not develop in these spots and when the film is placed in the fixing bath clear spots of transparent gelatine will appear. Airbells on the plate during development will have the same effect as particles of dust. If the plate is hurriedly fixed a small spot of unfixed emulsion may remain in the center of the white spot, as the fixing bath will work more slowly where the developer did not penetrate. Airbells are caused by air bubbles clinging to the plate during development. When developing in a tank airbells can be removed by drawing a card over the surface of the developer before immersing the film in the developer. Airbells may also be caused by dissolved air in the developer. Water will dissolve air and other gases. The higher the temperature, the less soluble is the air in the developer. Therefore, if a developer is warmed the dissolved air is driven out. Thus it is possible for airbells to form on

the inside of the tank if the temperature is raised. This can be overcome by allowing the developer to stand a short time at the required temperature before use.

Chemical dust is also a cause of white spots. Floating chemical dust may settle on the plate either before or after development. The sensitiveness of the film to light may be destroyed by particles of chemicals settling on the film before development. Hypo dust, especially, will dissolve a portion of the emulsion before development, causing a clear white spot. Usually a small spot is left in the center under the particle of hypo and is brought out in the developer, leaving a white round spot with a dark spot in the center. Particles of potassium ferricyanide on a moist plate during drying cause fine white spots which usually have a tail like a comet.

Patches and Streaks.—Patches and streaks may be either black or white as in the case of spots. *Black patches or streaks* may be due to:

1. Uneven development caused by neglecting to revolve the developing tank.
2. The film being splashed by the developer before developing.
3. A dirty tank, or using a fixing tank, for developing.
4. Light fog—if the edges of the plate are clear, the trouble is in the camera, but if fogged it is due to manipulation in the darkroom (see "Fog").
5. Certain kinds of resinous wood, varnishes, etc., will cause dark fog patches.

White patches or streaks may be due to:

1. Some obstruction in the camera which prevented the entire light from acting on the film.
2. Oil or grease which will prevent the action of the developer.
3. A splash of hypo, or touching the film when the hands are wet with hypo. The hypo dissolves more or less of the emulsion so that when developing, the portion affected by the hypo appears lighter than the rest of the negative.

Distortion.—Distortion of the film is due to softening or melting, due to the wash water being too warm or to drying with air that is too warm.

Drying Marks.—Drying marks will occur in the form of tear drops or white patches caused by splashes of water on a dry nega-

tive or by not wiping the spots of water off the film before drying, especially if the film is dried in warm air.

The Mackie Line.—A Mackie line is a dark line running along some outline in the negative where a dark object is contrasted against a bright background, as for example, a house against the sky. When the negative is printed the result is a disfiguring white line. The cause is local exhaustion of the developer. This will occur only when a weak developer is used. It will not occur if the tank is revolved during development. Instead of a dark line there may be a streamer of extra density running from a shadow to a highlight. The cause and prevention are the same as above.

No Image.—This is usually caused by the failure to expose the film, but it may be due to the omission of the alkali or the reducing agent from the developer.

Scum.—If a developer is allowed to stand in a tank for any length of time, the surface of the solution will become oxidized and form a scum. When immersing the film in this developer, the scum attaches itself to the gelatine and prevents the action of the developer. The precaution is to use only fresh developer.

Fog.—A deposit or veil on a negative or print which does not form part of the image is known as fog. The effect is to reduce the contrast of brilliancy in much the same manner as a mist or fog dims a landscape. It is for this reason that the veil of silver is called fog. A distinction must be made between overexposure and fog. Fog usually occurs over the entire plate, though it may occur in patches of any size. There are two kinds of fog, light fog and chemical fog, or there may be a combination of the two.

Light Fog.—Light fog is due to a light leak in the magazine of the camera, or to an unsafe dark room.

Chemical Fog.—Chemical fog may be caused by the following:

1. Chemical fumes: If the unexposed films are stored in a room containing traces of coal gas or hydrogen sulphide the sensitive emulsion of the film will be so affected as to make it developable without exposure to light.
2. The developer:
   a. Too energetic a developer, even if fresh and mixed correctly, may give fog. Some emulsions are more energetic than others. That is why a developing formula is given for each type of emulsion. A developer may be made more energetic by increasing the concentration and rais-

ing the temperature, or by adding too much carbonate. That is why a developer should not be used stronger or at a higher temperature than recommended. Forcing the development or prolonging the development beyond the usual time may also produce fog.

b. Oxidation products of the developer generally cause fog. To prevent oxidation it is important, when mixing the developer, to use sufficient sulphide and to use water that is free from air. Care should also be taken to prevent any undue oxidation while mixing the developer. Never add the carbonate to the reducing agent before adding sulphide, and do not unnecessarily warm the developer.

c. The presence of salts of metals as copper, brass, and tin in the developer should be avoided. A salt of copper if present in a developer to the extent of one part in 10,000 will produce fog on some emulsions. Therefore, it is important that there be no exposed brass or copper on the developing tank.

Dichroic Fog.—This is a particular form of chemical fog occurring only on negatives and lantern slides, usually in the form of a stain which is yellowish green by a reflected light, and reddish-pink by transmitted light. Its name is explained by this characteristic. Dichroic fog means two-colored fog. The stain consists of fine particles of silver and may be caused by underexposure and forced development with a developer containing a solvent of silver bromide, or by the use of a weak fixing bath or one containing an excess of developer. This fog occurs mostly in the shadows where there has been the least light action, as it is in these parts that there is no bromide liberated from the emulsion by the development. A characteristic of dichroic fog is that it is almost entirely at the surface while other chemical fog is deposited within the body of the gelatine film. This fog may often be removed by moistening the negative and rubbing with a damp cloth, or by an application of a weak solution of ferricyanide reducer.

Dichroic fog may be prevented by making certain that the fixing bath is acid and correctly prepared, and by rinsing the film well before fixing. If the trouble is still encountered below 70 deg. F. the trouble is in the developer.

Stains on Negatives.—The commonest yellow stains are oxidation and silver stains. Oxidation stains are caused by oxidation of the developer. These stains may be either general or local. General stain extends over the entire surface of the film, being caused by using an old developer or by a developer containing an unusual amount of sulphide. Pyro will give this stain, especially if the solution has been allowed to stand for any length of time before use. Forcing development in an unclean tray will also cause stains on prints. Local stains are the result of the acid fixing bath becoming neutralized by the alkali carried from the developer.

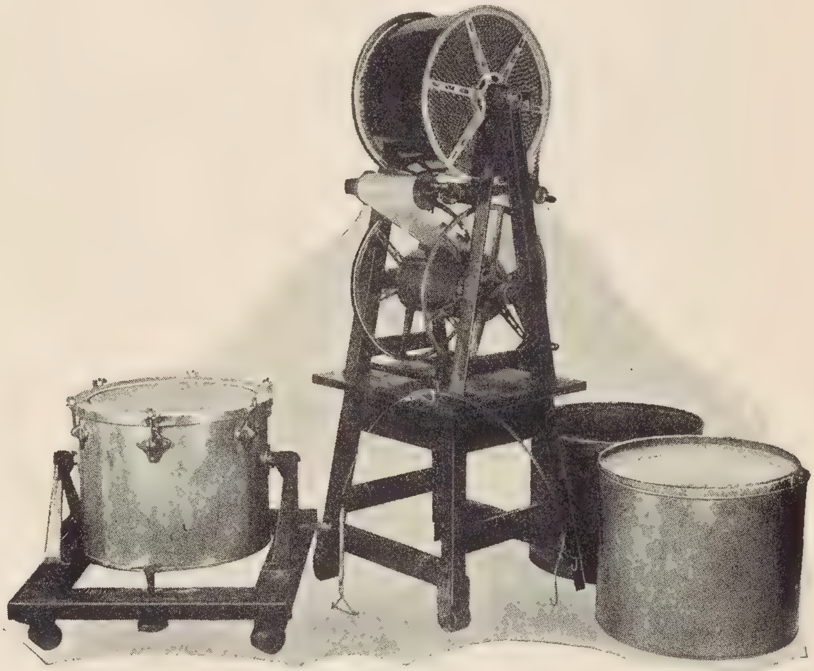
The other common stain is silver stain. By ordinary observation it is difficult to distinguish oxidation stain from silver stain. Silver stains may arise from one or both of the following causes:

1. By using an old and exhausted fixing bath which would contain an excess of silver in solution. If the film is not sufficiently washed, some of the silver salt remains. This is colorless but changes to yellow silver sulphide when exposed to the air.
2. If the negatives have not been completely covered while in the fixing bath, although they may appear completely fixed in spots they may nevertheless have been fixed only as far as the first stage, with the result that on exposure to the air yellow stains will appear.

The Eastman Aero Film Developing Outfit.—This consists of a transfer fixture mounted on a stand. On the transfer fixture are two interchangeable reels which are placed on the transfer, one at the top and one at the bottom. On the reel placed at the top an apron of kaloid is wound. This apron is so constructed that when wound the kaloid is held apart so that the film can be wound within it. There is sufficient space to permit the developer, fixing bath, and rinsing water to reach the film wound within the apron without the emulsion of the film touching any part of the remainder of the film or any part of the apron. Between and in front of the two reels, when placed on the fixtures, a spool containing the film is placed. To both reels and the spool of film, cranks are attached. With the developing outfit are four tanks; one for developing, two for rinsing and one for the fixing bath. With the developing tank is a fixture consisting of two journals mounted on a carriage sup-

ported by four heavy casters. The developing tank is placed on this fixture between the two journals and so arranged that the tank can be turned with the crank. There is a cover which will fit all four tanks so as to keep out the light and retain the liquid when the tank is reversed.

Drying Reel.—The drying reel is a circular drum about 8 ft. in diameter by 8 ft. long, built of skeleton design, the two ends being similar to a buggy wheel, with slats 8 ft. long connecting them.



U. S. Army Air Corps

FIG. 36.—K-1 DEVELOPING OUTFIT

The slats are placed about 2 in. apart around the drum. This drum turns on an axle, the two ends of which run on bearings. These bearings are on a stand of sufficient height to have the drum clear the floor by about 2 ft. The drum is driven by a motor and revolves at about 500 r.p.m.

Developing with the Eastman Developing Outfit.—The development is done in total darkness. Therefore everything must be placed where it can be found and used. The order of developing is:

1. Place the four tanks in the sink or drain. Put the developing tank on its stand, arranging so that it can be revolved. Stand the lid for the tanks against the developing tanks. Fill the developing tank with the correct developer for the film to be developed. Fill one of the rinsing tanks with water, and the fixing tank with the fixing bath, putting the rinsing tank between the developing tank and the fixing bath.

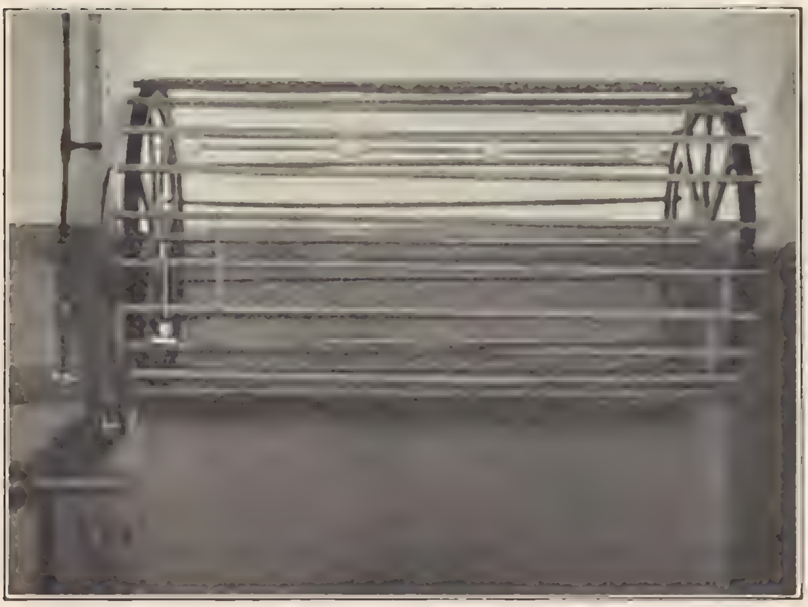


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Fig. 37.—Film Drying Reel (Army Construction)

2. Place the reel containing the kaloid apron upon the top receiver of the transfer fixture so that it will unwind from the rear of the fixture, considering the front as the part that the spool of film goes on, and the empty reel on the bottom receiver. Then attach the apron to the empty reel, bringing it down the rear of the fixture. Take a few turns of the apron on the lower reel by turning the lower crank. Being sure everything is in its place, the lights are now turned off and the door to the developing room closed. Before the can containing the film is opened, allow your eyes to become accustomed to the darkness. Then inspect for any light leaks.

If there are none, the film may be removed from the container.

3. The film is then placed on the transfer fixture so that the emulsion side of the film is up when attached to the reel. Attach the end of the film to the apron on the lower reel. This is done by using three strips of adhesive tape about 6 in. long, that were placed on the fixture stand before the lights were turned out.
4. The film is then wound onto the lower reel by standing in front of the fixture and turning the lower crank clockwise. Turn the crank very slowly and allow no slack in either the apron or the film. The left hand should guide the upper reel so that the reel travels at the same speed as the lower one. Care must also be taken to see that the film is tight at all times. These operations make it necessary for two men to do the work.
5. When all the film has been wound on the lower reel continue to wind until the remainder of the apron is off the top reel. Then place the strap (furnished for that purpose) around the full reel. Remove the reel from the transfer, placing it in the developer, a hook with a handle being furnished for this purpose. Put the lid on the developing tank, clamping it down tight. The lights can now be turned on. Leave the film in the developer for the required time given in the developer formula. While the film is in the developer, the developing tank should be reversed every $2\frac{1}{2}$ minutes.
6. When the development is completed, the lights are again turned off. The reel is then removed from the developing tank and the film is then rinsed in the rinsing tank and placed in the fixing tank. The lid is put on the fixing tank and clamped down. The lights are again turned on. The reel is left in the fixing tank for one-half hour, then removed and placed in the washing tank or sink and washed for one-half hour.
7. If the washing is done in the tank a hose should be placed on the bottom of the tank so that the water will come from the bottom through the reel and flow over the top. To wash in the sink, see description of sink under "The Design of a Photographic Laboratory."
8. After the film has been washed, the reel is then placed on the

top of the transfer stand and the apron connected to the empty reel which has been placed on the lower receiver of the transfer. The transfer is then moved in front of the drying reel. As the apron is wound onto the lower reel the end of the film, as it appears, is fastened to a clip which is attached to the drying reel by rubber bands about 12 in. long. These bands are to take up the slack in the film. The film is then wound on the drum in a spiral and the apron is wound on the other reel at the same time. When the end of the film is reached it is also fastened to a clip attached to rubber bands. The film is then gone over lightly with a soft chamois or a damp piece of cotton to remove excess water. If this is not done the film may be spotted with water drops. Then the reel is started by first turning by hand and then starting the motor. After the film is thoroughly dry it is rewound on the spool which is on the transfer. It is then ready to be inspected before printing. The used apron should be thoroughly dried before being put away.
This can be done by winding it from one reel to the other and wiping with a chamois. If the developer is to be used again the cover must be put on the developing tank and clamped down tight. The fixing bath should be covered to keep out any dirt or other matter.

An English Developing Outfit.—This developing apparatus consists of a rotor and stand, a nest of tanks, and a drying drum. The rotor is a drum-shaped brass framework provided with radial guides on the inside faces to carry ebonite spacers. The stand is a casting provided with a filling for holding the spool of film and slots for receiving the spindle of the rotor. A tray for holding the ebonite spacers is mounted on the base. The developing tanks are made of nickel (98 per cent) and are three in number, the largest of which is provided with a cover, whereas the two smaller tanks nest inside of the larger. The lid may be used on any of the tanks.

Drying Drum.—Each alternate slat is spring-supporting in order to take up the shrinkage of the film. This drum should not be revolved at a greater speed than 100 r.p.m.

CHAPTER XI

PRINTING

In photography the process of making positives from negatives is termed printing. Printing is accomplished by passing light through the negative onto a piece of printing paper taking the place of a stencil.

Printing Paper.—Generally speaking, printing paper is made the same as plates or films with the exception that its base is paper instead of glass or film. When printing from a negative its scale of tones must be reproduced on the printing paper. An average of 100 tones that can be detected by the eye can be printed on most printing papers. The scale of a printing paper is determined by the range of exposures that will give these tones, that is, if an exposure of one second will show the first trace of a tint on the paper, and an exposure of twenty seconds will produce the deepest black the paper is capable of taking, then the scale of that printing paper is one to twenty. Printing papers having different scales are made to be used with each type of negatives.

Scale of a Negative.—The scale of a negative is the range of light intensities transmitted by it. For example, in a very contrasting negative, the blackest part will let through only one-hundredth of the light transmitted by the clearest portion. In a negative of medium contrast the blackest part will let through one-twentieth of the light. In a very flat negative (little contrast) the densest part will let through one-fifth of the light. With these negatives there would be three scales: the contrasting negative, one-hundredth; one-twentieth for medium contrast; and one-fifth for the flat negative.

Reproducing the Scale of the Negative.—The printing paper should reverse as nearly as possible the scales of light intensities recorded by the negative. When choosing printing paper it should reproduce the clearest part of the negative to the deepest black of which the paper is capable and only print slightly through the densest part of the negative so as to give a slight tint.

Control.—With rapid bromide paper there is considerable control. The contrast of bromide paper increases during development. Thus when printing a flat negative a short exposure can be given and developed fully so as to obtain a full scale of tones from white to black even though the negative has a limited range of densities. When printing a contrasting negative on bromide paper, expose fully and shorten the development so as to lengthen the scale of the paper.

Printing Papers Recommended for Aerial Photography.—Among the papers recommended for aerial photography are alloyed pressed bromide double weight matte, P.M.C. bromide double weight, No. 4 (glossy), and No. 6 (matte), and Aerox, a new paper which has been tested and proven to meet the requirements of aerial photography. For oblique work, Azo and Velox can be used. The U. S. Army Air Corps requirements for printing paper are three or four degrees of contrast that can be developed to the same tone, on white stock with quality at least equal to that of Velox, and a latitude in manipulation comparable to that of Azo.

Correct Exposures.—The correct exposure for printing is that which prints just through the highest density of the negative so as to produce the lightest possible veil in the highest density. The following factors control the exposure: 1. the sensitiveness of the paper; 2. the intensity of the light used; 3. the density of the negative. Numbers 1 and 2 are constant, therefore the problem of determining the correct exposure resolves itself into judging the density of the negative.

Standard Set of Negatives.—Every photographic laboratory should have a standard set of negatives. With each negative the following information should be filed.

For Printing:

1. A print on each type of paper used.
2. The exposure given on each paper for every negative.
3. The number of lights and watts used.
4. The developer used.
5. The time of development.

The above information should be given for enlargements and for reductions.

General Information on Taking and Developing the Negative.—

1. The plate or film used and the time and date of manufacture.

2. Type of filter, if one were used.
3. Time of exposure (taking the picture).
4. The month, day, and time of day taken.
5. Kind of day (hazy, cloudy, etc.).
6. The locality where the picture was taken.
7. The focal length of the lens used.
8. The altitude at which the picture was taken.
9. The developer and time of development.

The only possible way to turn out uniformly good work is by using the information contained in a standard set of negatives. This will make it possible for any member of the staff to perform any duty connected with the laboratory work. Much time and material will be saved by using the above method.

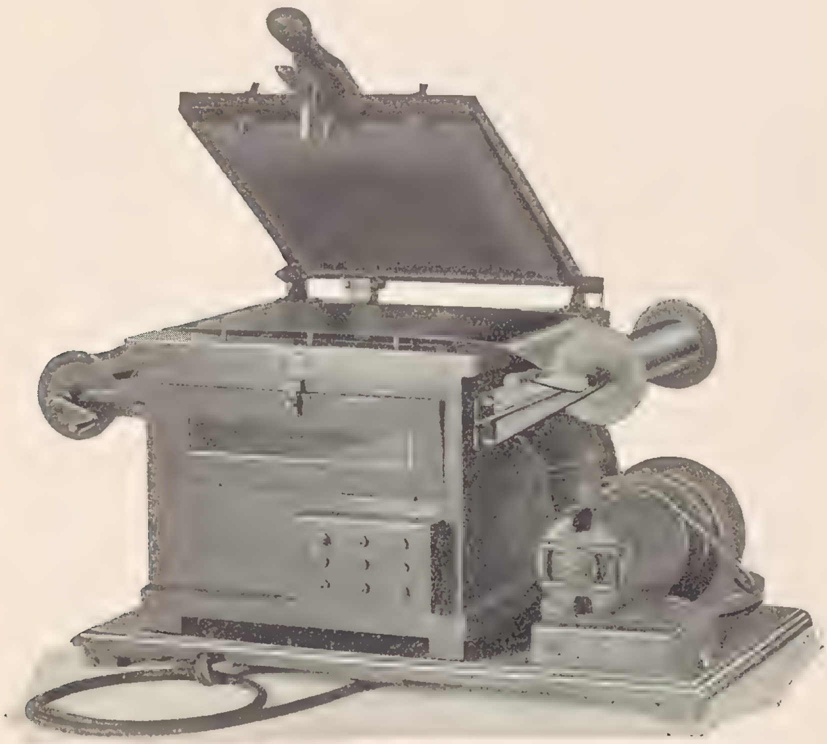
Stained Negatives.—More exposure will be required for stained than unstained negatives. The amount of exposure depends upon the color of the negative. If stained negatives are often used it will be necessary to make a set of standard stained negatives.

Methods for Printing.—There are two general methods used in printing: contact and projection. The former produces a print the exact size and scale as that of the negative and has all its inherent faults. Contact printing is the fastest and most economical method. By the latter method, projection printing, the picture can be enlarged, reduced, and rectified.

Contact Printer.—This machine consists essentially of a box with an optically corrected glass top over which the film passes. Enclosed within the box are several rows of electric lights that are so regulated that when the lid is raised the white lights are extinguished and a small red light burns; when the lid is pressed down any desired number of the white lights may be switched on. There are spools on either side of the box to hold the film. By turning one of these spools any desired negative on the roll can be wound over the glass into position for printing. The lid of the printer consists of a pneumatic or felt pad. Its function is to hold the film and paper in perfect contact during printing. The printer is also provided with an air blower that circulates the air so as to cool the printer when in constant use.

Contact Printing.—Exposing the print, developing, and fixing are done under a safe light usually orange or red in color. The roll of film is placed on one of the spool containers, then brought over the glass top (with emulsion side up) and connected to the

empty spool on the other side of the printer. When the negative to be printed is over the glass, the printing paper is then placed over the negative, emulsion side down. That is, the film and paper will be emulsion to emulsion. The lid is then pressed down, automatically turning the lights on. After the printing paper is exposed by this means for the required time, it is removed from the printer and immersed in the developer, face up and with a sliding



U. S. Army Air Corps

FIG. 38.—K-1 CONTACT PRINTER

motion, care being taken to wet the entire surface of the paper immediately. If airbells form on the surface of the print they must be removed by rubbing with the fingers. A standard developer requires from one to one and a half minutes to develop a normally exposed print, the time varying with the exposure given, the paper used, and the strength of the developer. The temperature of the developer should be from 65 to 70 deg. F.

Fixing.—On the completion of development the print is quickly washed off in clear, clean water, then placed in the fixing bath, face up. Care must again be taken to remove all airbells. From five to six minutes are required for thorough fixing. For the first few seconds after being placed in the fixing bath the print should be kept in motion to allow even fixing. When fixing several prints at a time care must be taken to keep them separate. Sixty-four

U. S. Army Air Corps

FIG. 39.—PRINT WASHING SINK (ARMY CONSTRUCTION)

ounces of Hypo solution will fix about one gross of 7 × 9-in. prints.

Washing.—After the print has been thoroughly fixed it must be washed to remove all traces of chemicals which the paper has absorbed, especially the Hypo. The print should be washed about 15 minutes in running water, or with approximately ten changes of water.

Dodging.—Contact prints are dodged by placing sufficient tissue paper directly under the thin portion of the negative to hold back that part until the heavier portions have a chance to come up.

The amount of tissue paper to use can be determined by the light which passes through the heavier and thin portions of the negative.

French Contact Printer.—A rapid printing device for aerial photographic film with an automatic adjustment bearing the light intensities has been developed in France. This printing device consists of a light box containing a tubular electric lamp covered by a glass plate, over which the negative and the bromide paper pass, coming from reels located on the side of the printer and passing between rollers, then being rewound on reels on the opposite side of the printer. These reels are under tension to secure perfect winding. The variation of the density of the light for different quality of film or for various sections of the same film is accomplished by the automatic variateur. Eight different light intensities are available. On examination of the film it is possible to determine the intensity of the light required for printing each section. A notch is made in the edge of the film at the beginning of each section. Where a variation is desired a cardboard guide is then punched with holes for the insertion of plugs and placed on the switch board, thus setting up the desired changes of light intensity throughout the entire length of the film to be printed. The printer is actuated by a small electric motor. As the film passes through the printing device, the notches, previously placed in the edge of the film, pass through the interrupter allowing a momentary contact and thus producing a change in the light intensity in accordance with the scheduled arrangement upon the switchboard. This device can be used to print negatives of all sizes up to 18 × 24 centimeters. The hourly production of prints is said to be from 2,500 to 5,000.

Printing by Projection.—The enlarger is opposite in principle to a camera. The light first passes through the negative and then through the lens or the condenser, which in turn projects the picture recorded by the negative onto the printing paper. While contact printing gives a true print of the image as recorded by the negative, projection printing allows changes to be made in the size and angle of the images.

ENLARGING

Enlarger.—Any camera can be used as an enlarger. By placing, in the camera the negative to be enlarged and passing the light through the negative and the lens, which is left open, the image is

projected onto the easel. This method, however, is not practicable for the class of work done in aerial photography. It serves rather as an explanation of the principles involved in the construction of an enlarger or a projector.

The enlarger consists of a metal body containing a light and a negative holder, a condenser between the negative and the light, and a projection lens which is an astigmat of high quality corrected for photographic work.

Condensers.—If the apparatus is used without condensers only the center of the negative can be properly illuminated and enlarged. Though the light will reach all portions of the negative the only light to reach the lens is that which has been passed through the part of the negative which lies in a straight line between the light source and the lens. In order to illuminate the entire negative evenly, it is necessary to arrange the condenser so that those rays from the light that reach only the edges of the negative will also pass through the projection lens, this being accomplished by means of a lens which will bend the rays of light from the lamp so that they will pass through the projecting lens. This lens is called the condenser. The condenser must be adjusted to the focus of the projection lens in order that the rays of light shall be focused just in front of the projection lens. This point at which the rays of light can be so focused can be found by varying the distance of the light from the condenser. The evenness of illumination upon the screen will depend upon finding this distance correctly. If the light is too near the condenser the focus of the condenser will be too far in front of the lens and the center of the field of the projected light will not be properly lighted. This will be indicated by a dark spot in the middle of the field. If the light is too far from the condenser the rays will meet before they reach the projection lens and the margins of the field will not be properly lighted.[1] In order to cover the negative the condenser must be larger than the negative that is being enlarged. When using a 7×9-in. negative a condenser of about 14 in. should be used. Although somewhat larger than necessary it will insure evenness of illumination to the extreme corners of the negative.

[1] Before using the enlarger the following adjustment should be made. Remove the negative carrier, then project the light on a sheet of white paper fastened on the easel. By centering the lamp and then adjusting its distance from the condenser even illumination can be obtained.

Focusing.—Focusing should be done at full aperture. If trouble is found with the negative to be used, as in the case of a very dense negative, a normal negative or a specially prepared plate should be used for focusing. The latter is made by using a discarded dense negative and scratching lines across so as to leave clear marks. After focusing with this standard negative, the negative to be printed is then put in its place, care being taken not to disturb the adjustment. It is not necessary to refocus for each negative if they are to be projected to the same size. After focusing as sharply as possible the lens should be stopped down until the whole field is sharp. This can best be determined while the test negative is still being used.

Procedure in Enlarging.—1. First see that the lens is clean and the condenser is free from water vapor.[1] If the condenser is not clean, light the lamp for a half hour before using. Do not wipe off the condenser unless it is absolutely necessary. If it is necessary, remove the condenser from the enlarger and wipe lightly with smooth leather or a clean soft cloth and apply a little heat to remove all moisture.

2. The enlarger and easel must be parallel. To check, measure diagonally from each edge of the body of the enlarger to each corner of the easel.

3. Check the illumination and focus.

4. Stop down the lens to about *f.* 11 or *f.* 16.

5. Place in the negative carrier the negative to be projected, with the glass or film side facing the condensers and the emulsion side facing the projecting lens.

6. The amount of exposure depends upon the speed of the paper, the strength of the light, the density of the negative, and the size of the enlargement or reduction.

Dodging.—When enlarging, dodging is usually accomplished by placing the hand or other object between the lens and easel in the path of the light so as to cast the desired shadow. In this manner the brighter area in the projected image can be held back so that the other portions that form the denser areas can be printed. This will insure an even print.

Development.—The development is accomplished in the same manner as that given under contact printing. Special care should

[1] The condenser will sweat at times during cold weather due to condensation of the water vapor in the air.

be exercised to insure that the entire surface of the print is covered by the developer at once.

THE EASTMAN PROJECTION PRINTER

This printer consists of a table or horizontal easel on which the printing paper is placed. From the table extends an upright arm from which a camera is suspended above the table. The camera contains the lens pointing directly downward so as to project the image onto the easel. Flexible bellows connect the lens board to a back on which the negative is placed. This camera is so suspended that it may be raised or lowered, and in this operation the lens automatically moves to the required distance, with reference to the negative, so that the projected image on the easel is always in focus. With the projection printer, enlargements or reductions can be made almost as fast as by contact printing.

THE RESTITUTIONAL PRINTER

This printer consists of a light source and a pair of condensing lenses through which the light is projected, the beam passing through the negative, then through a photographic projection lens to the sensitized material. This printer is used for making prints of a uniform scale from negatives which have a varying scale, caused by the tilt of the camera at exposure. This is accomplished by the negative holder, the lens, and the paper holder being rotatable about the horizontal axis and having the negative holder and the paper holder also rotatable about the optical axis of the lens. This camera may also be used with the holders vertical for making normal prints, enlargements, or reductions. The printer consists essentially of a lamp house and a condensing lens carriage, negative holder stand, lens holder carriage and paper holder carriage, all mounted upon a metal bed. The negative holder, lens holder, and paper holder, as stated before, can be rotated about the horizontal axis. The negative holder has an adapter which carries a single negative which is rotatable in its own plane. With these motions and the necessary control being available for altitude and tilt of the negative, rectification and transformations can be made to any angle within the range of the adjustments.

For normal enlarging all of the holders are set vertical with the cut film between glass plates in the single negative holder. An

8 × 10-in. magazine holder for paper and an easel which fits into the keyholes on the paper-holder brackets are furnished. As the lens furnished varies slightly in focal length a table should be made for each lens giving settings for lens and paper-holder carriages for various enlargements as determined by actual trial. For the rectification of negatives it is necessary to cut the negative from its roll and mount it in the rotating negative holder. At least three, and at best four, points of control must be known. This ground control is then laid off to the required scale and a piece of paper attached to the circular paper-holder. The negative holder and the

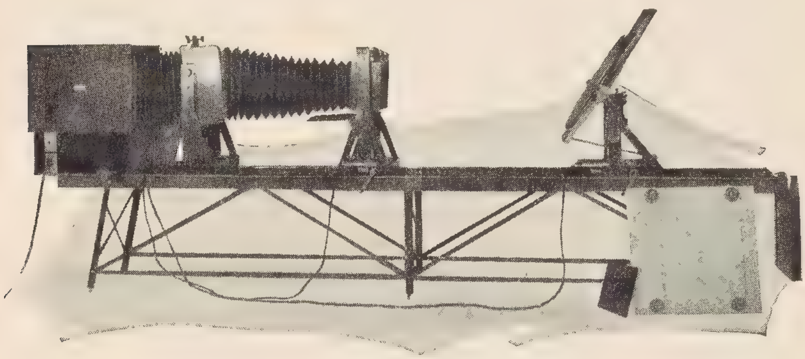


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Fig. 40.—Restitutional Printer

paper-holder, by cut-and-try-methods, are then rotated and tilted until coincidence is obtained. The lens is then rotated until the plane of its mount, the plane of the negative, and the plane of the paper intersect the same line.

DEFECTS IN PRINTING

The following is a list of the most common defects occurring in contact printing:

- Bad Definition in Spots—Due to insufficient pressure in printing frame (not in contact).
- White Spots on Prints—Due to dirt on negative or paper, or airbells forming on surface of print during development.
- Finger Marks—Due to finger prints on negative or paper. The dry paper must never be handled with wet or greasy fingers.
- Fog: the high light of prints appears gray—Due to unsafe light, or perhaps some white light, forcing development, etc. (See "Fog.")

Light-Struck—The paper is accidentally exposed to white light.

Uneven Development—Usually caused by prints overlapping one another in the developer and not being separated often enough during development.

Uneven Fixing—Prints not separated often enough in fixing bath. Airbells forming on the surface of prints fixed face down will prevent the acid fixing bath from acting evenly, development proceeds, forming a dark spot.

Yellow Stains—Caused by: (*a*) Weak and exhausted fixing bath; (*b*) forced, prolonged development; (*c*) not properly rinsed before fixing; (*d*) unclean fingers; (*e*) unclean trays; (*f*) hypo solution being carried into the developer.

Brown Spots on Prints—Generally caused by loose chemical settling on the prints while drying.

Muddy tone; prints appear flat and muddy—Due to overexposure and too short development; probably temperature of the developer is too high.

Green Contrasty Prints—The developer is weak, or contains too much bromide. Replace with fresh developer.

Blisters—Blisters generally appear on the print after fixing and in the washing.

Scum on the Surface of Prints—Usually caused by old developer or old fixing bath. May be removed by sponging prints after washing.

Streaks and Abrasion Marks—Due to (*a*) old or stale paper; (*b*) friction against the sensitive side of the paper. They are prevented by adding a little potassium iodide to the developer. Removal: (*a*) Rub the dry print with a tuft of absorbent cotton dampened with alcohol; (*b*) treat with a solution of iodine in potassium cyanide.

THE T-1 TRANSFORMING PRINTER

Purpose of the T–1 Transforming Printer.—The T–1 transforming printer, by projecting the negatives through the required angle, brings the photographs taken with the oblique lenses of the T–1 aircraft camera onto the same plane as that of the photograph taken with the center lens. The photographs from the oblique negatives, labeled *A* and *C*, and the center photograph, labeled *B*, may then be so mounted and joined as to form a single composite picture. The printer is adjusted for use with only one T–1 aircraft camera, the camera and printer bearing the same number must be used together.

Vacuum Photographic Paper-holders.—Each paper-holder is provided with a vacuum back which keeps the photographic paper flat against the plate, bringing it accurately into the focal plane. The holders accommodate sheets of paper 9 × 10 in. in size. Only double weight bromide paper should be used. Each holder has a slide, which, of course, must be removed during exposure. Six holders are supplied in order to speed work with the printer when it is being used in a lighted room.

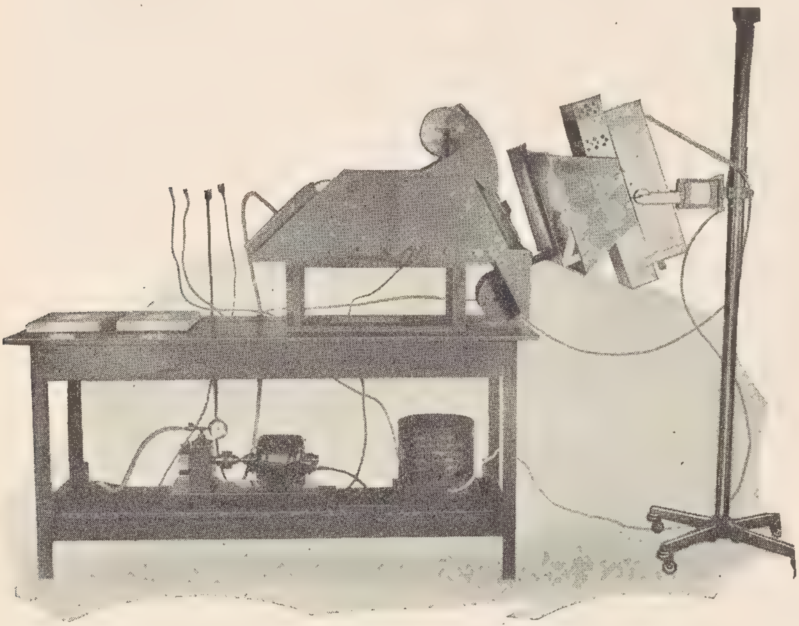

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Fig. 41.—T-1 and T-2 Transforming Printer

This printer transforms to a true vertical scale the oblique photographs taken by the T-type cameras.

Shutter.—A shutter, which acts when switching the interior light on and off, facilitates the operation of the printer in a dark-room, when two men are working together, by automatically protecting the sheet of photographic paper in the paper-holder from light passing through the lens. The man looking after the loading of the paper-holder is not interfered with by the man attending to the negatives and light.

Spool Brackets.—When the printer is packed for shipment, the spool brackets are mounted on plates provided inside the

printer on the paper-holder side of the lens. The empty spool belongs in the top set of brackets; the spool with negatives to be reproduced, in the bottom set of brackets with the glazed side of the film outward. The brackets are equipped with cranks and friction brakes for winding the film.

Incandescent Electric Lamp.—The purpose of the electric lamp is to illuminate the negatives when they are being set in place.

Vacuum Pump with Electric Motor.—The vacuum pump is equipped with connecting wire and switch, rubber hose, and a pressure indicator. It is connected with the vacuum paper-holder, for which it supplies the required vacuum. Attached to the end of the rubber hose is a nozzle which fits into the stem of the paper-holder to form the vacuum connection. This connection is broken by pulling the nozzle off the stem.

Negative Holder and Punch.—The negative holder has a small metal post mounted on its face. Negatives that have been properly punched fit into place when slipped over this post and aligned on the holder. The punch is used to punch the small hole required in the margins of the negatives. It has a flat duralumin (or brass) plate for the negatives to rest upon, this plate being inset with three disks on which are scribed straight lines that, prolonged, cross each other at right angles. To give the negative the correct position for punching, it is so placed that its notches fall on the scribed lines of the punch. The oblique negatives of the T–1 aircraft camera are labeled *A* and *C* by stencils at exposure, the labels being at the outer edges. When punching the negatives, it is requisite that the stencil fall at the right-hand side of the operator and that the celluloid side of the negative be up. A metal plate keeps the negative flattened against the duralumin plate. Negatives labeled *A* will be punched with the holes near one edge of the roll; negatives labeled *C*, with the holes near the opposite edge of the roll.

Arc Light.—The arc light for either direct or alternating current is of the standard commercial type commonly employed in studios, has two arcs, and requires a 30-ampere, 110 or 220-volt current. Instructions for installation and enough carbons to keep it lighted about 2,400 hours accompany each light. The light is equipped with a diffusing-glass holder which permits the holder to be so tilted about its bottom edge as to secure the degree of illumination that will give uniform density to photographs.

Operation of Printer.—After the *A* and *C* negatives have been punched as described above, open the glass door of the negative holder and with the spools inserted in the brackets as explained before, attach the end of the roll of negatives to the empty spool and wind it until the first oblique negative comes into position. The stencil (number of camera and negative) of the negative must always be set toward the top spool when the negative is put in position for exposure. Turn on the interior light, drop the negative over the post, close the door, and adjust the negative until the upper and lower notches fall onto the short lines on the supporting glass plate. It is very important to obtain coincidence between the lines on the negative and those on the glass.

Insert a loaded paper-holder, attach the vacuum tube, and turn on the pump and the arc light. Adjust the arc light to the height that will bring the arcs on a level with the center of the negative. Incline the reflector somewhat toward the negative and see that the arcs are about 12 in. from its center. Stand the diffusing glass about parallel with the front of the reflector, but if the light is not well distributed when the diffusing glass is parallel to the reflector (as shown by a test exposure), incline the diffusing glass slightly with its top leaning away from the reflector. A few trials should give the correct lighting. Use two or three pieces of the diffusing glass for thin negatives, a single piece for denser negatives. When exposures are long, the heat developed by the arcs may be so great as to endanger those parts of the roll of negatives which are exposed to the heat. The heat guards, therefore, should always be set to protect the negatives on and near the spools.

Draw the slide and expose the required length of time, exposures being made by throwing the switch which controls the shutter. For fully exposed and slightly stained negatives, using *f*. 4.5 stop, the exposure time required is from 2 to 10 or more seconds. For negatives with heavier stain, the time required is greater according to the amount of stain. Fully developed and heavily stained negatives may require from 30 to 40 seconds exposure. Stained negatives give better photographs than unstained negatives. Film exposed in T–1 aircraft cameras should therefore be developed with U. S. Army Air Corps tank developer. The lens should be used with stop *f*. 4.5 unless great speed is essential. Replace the slide after exposure.[1]

[1] When working in a darkroom, the slide may be dispensed with and the

THE VACUUM PRINTER

This printer is designed for making contact prints from 20 × 24-in. negatives. It works on the vacuum principle of holding the negative flat during the exposure. The vacuum pump draws the air from the space between a rubber pad and a plate of glass, holding the negative snugly against the glass.

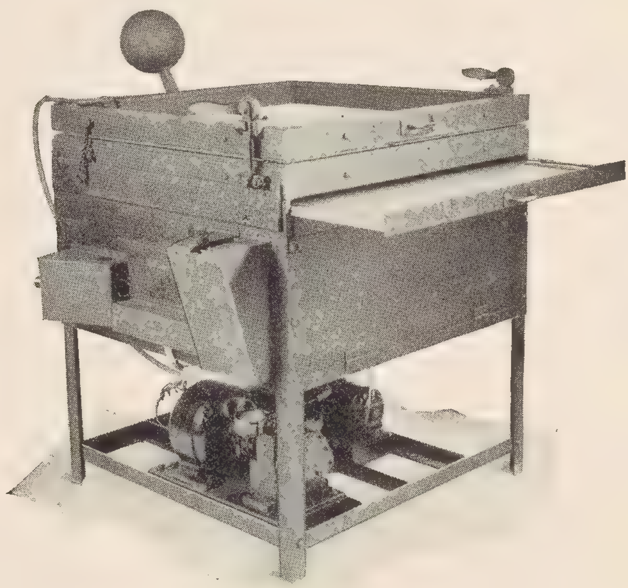

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Fig. 42.—Type M Printer
For large negatives—to 24 × 24 in.

The printer is equipped with 48 to 75-watt frosted bulbs and two red lights. The printer is cooled by a small blower operated by a 1/20-hp. motor.

The vacuum pump is operated by a separate 1/4-hp. motor.

Operation.—1. Turn on the main switch, which will be found to the left and rear of the printer.

paper-holder loaded while in position on the printer. It also facilitates the withdrawal of the exposed paper to leave the vacuum pump on until the back of the holder is swung open, and then turn the switch. The exposed sheet drops off.

2. Place the negative, emulsion side up, on the plate glass; then place a piece of printing paper, emulsion side down, on the negative.

3. Lower the lid and fasten on both sides with the clamps.

4. Turn on the vacuum pump. (The release valve at the back and on top should be closed.)

5. Turn on the light switch at the left of the printer.

6. After the required exposure has been given turn off the switches in the reverse order in which they were turned on.

7. Open the release valve so as to break the vacuum.

MAKING PRINTS FOR A MOSAIC

There is some difference of opinion as to the best tone of prints for constructing a mosaic. Some operators prefer the prints to be a little flat or a blue-gray while others want a normal print. When the mosaic is to be copied the former method is probably better. Whatever tone and shade is decided upon, however, each print must be matched perfectly with the others.

Prints may appear at a glance to be exactly the same, but by careful study the same prints are often found to be different in contrast. When a mosaic composed of prints of different contrast is printed, the light reflected will make it impossible to obtain a good copy. The following factors should be considered when making prints to compose a mosaic:

1. The developer should be of a constant strength and, if possible, from the same batch of stock solution.
2. The temperature should be constant.
3. If potassium bromide is added the same amount should be put in each fresh tray full.
4. The developer should be changed frequently.
5. If a print does not match, the exposure time should be changed rather than the time of development.
6. If more than one roll of film is to be printed it may become necessary to change the grade of paper.
7. If another grade of paper is used, the amount of potassium bromide in the developer may have to be changed.
8. A timer should be used to retain a uniform time of exposure and development.

9. The strength of the light used for printing should be such that 10 seconds will be about the proper exposure.
10. In order to obtain a blue-gray tone, the print should be slightly overexposed and slightly underdeveloped.
11. A print should be made for a guide. This guide print should be examined in the daylight. It should then be hung over the hypo tray and all other prints compared with it as they are finished.

DRYING PRINTS

After a print has been thoroughly washed its surface should be swabbed with wet absorbent cotton.

There are several methods by which a print can be dried. Among them are the following:

1. *Squeegee Drying or Rolling.*—If sufficient hardener has been used in the fixing bath the print can be blotted off and the surplus water removed by a squeegee [1] or a print roller. The water is removed with the squeegee or print roller by placing the print face down on a board or similar object and the surplus water is forced out by running either of these instruments over the back of the print. The print is then placed face down on a drying stretcher. This stretcher consists of a frame constructed of wooden strips covered with mercerized cotton or other similar material. After the stretcher has been covered with prints it is placed in a drying rack. This rack is so constructed that the air is allowed to circulate under it and through the stretcher. Prints made for mosaic assembly should be dried by this method. They should not be rolled or squeegeed.

2. *Ferrotyping.*—Ferrotyping is a method for drying prints and giving them a glazed finish. Ferrotype plates are made of sheet metal coated with a hard smooth black enamel. These plates must be kept clean and polished. They are cleaned with hot water and polished with a soft cloth and ferrotype polish. The polish is made of:

Benzol or gasoline	15 oz.
Paraffin	150 gr.

[1] A squeegee is a strip of rubber mounted on a wooden handle.

If the plates are in good condition they may be washed in suds of castile soap and the wax omitted. The prints are placed on the ferrotype plate in the following manner:

a. Dip the plate into water to remove foreign matter.
b. Lay the wet prints face down on the plate by holding the print by the two diagonally opposite corners so as to form a loop. Then bring the bottom of the loop in contact with the

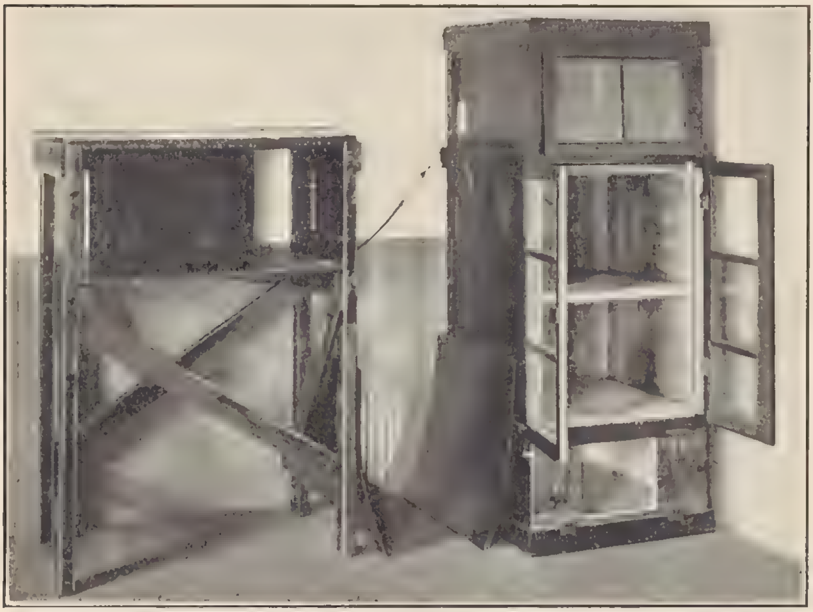

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FIG. 43.—PRINT DRYING CABINET, FERROTYPE RACK AT LEFT (ARMY CONSTRUCTION)

plate and lower each corner until the print lies flat on the plate.
c. Squeegee the surplus water from the prints.
d. Run the plate through a print roller (clothes wringer). The roller should be set so that the pressure will be just sufficient to insure the proper contact.
e. The prints are then allowed to dry on the ferrotype plates. As they dry they will release themselves from the plate.

3. *The Alcohol Method.*—After the surplus water has been removed by squeegeeing, the print is then immersed in an alcohol bath. The print should remain in the alcohol until the outline of the image can be seen through the back of the print. The surplus alcohol is then drained from the print. It is then placed between blotters and afterwards transferred to the drying stretcher.

CHAPTER XII

COPYING

Equipment.—The necessary equipment for copying is a camera having a long bellows, and a copy board or easel for holding the copy. The best camera for this work is a special camera known as a copying camera. The camera is mounted upon a substantial bed, with a front extension upon which an easel is fastened. The easel must be so placed that it is at all times square with the lens, and exactly parallel with the focusing screen. Any deviation from this position will cause distortion, and loss of definition in the reproduction.

The Process of Copying.—*Improving the Original Copy.*—Since every crease or spot of dirt will show on the negative, drawings or prints which are soiled or worn should be placed in the best possible condition before copying. The creases can often be removed from the print by wetting and redrying. A soiled print can be cleaned by sponging over with a little alcohol on a tuft of cotton, and a map or an ink drawing can be cleaned with sponge rubber or bread.

Placing the Copy.—The copy should be placed on the board so that the center of the copy, the horizontal axis of the lens, and the center of the focusing screen are in a straight line. The copy should lie flat upon the board, otherwise there will be distortion because portions of the reproduction will be slightly out of focus. If a copy is troublesome in this respect, a clean glass may be placed over the copy to hold it flat, although this method should be avoided if possible, since reflections from the glass introduce difficulties in the work.

Lighting.—Proper lighting is of great importance in copying, since uneven illumination is much more apparent in the reproduction than on the copy board.

If the lighting arrangements are not correct, reflections of the light source and other bright objects will show on the reproduction,

particularly with glossy prints, or prints held flat under glass. The operator can determine this by viewing the copy with one eye from a point directly in front of and as close to the lens as possible. It is absolutely essential to avoid such reflections.

If the illumination comes directly from the side (or top) the slight roughness on the copy casts minute shadows which give a grainy appearance to the reproduction, and this is increased by stopping the lens down. Creases are also exaggerated.

Proper Arrangement.—If the source of light is a window, use the light coming in from one side. By placing a white reflector on the opposite side throw the light from there and, by obtaining light from both sides, effect a uniform illumination of the copy. If natural light is made use of the light will not be constant. During the year the strength of the light varies. For copying, light varies even within as short a period as fifteen minutes.

Artificial Light.—On account of its steadiness and constancy, artificial light is best. There are several ways of arranging the lights so as to obtain proper lighting, but reflection into the lens must be avoided. The camera front should be in the shadow or screened. One way which has been recommended is to place a board between the easel and the camera. In this board provide a circular hole in the center large enough not to obscure the edges of the copy appearing on the focusing screen and arrange a series of lights around this opening on the side next to the easel. This gives the copy direct light from in front and yet allows no light to be reflected into the lens. Other methods of placing the lights can be devised. The following method can be arranged so as to avoid reflection:

Mark off on the copy board the largest sized copy to be made and focus this to the full size of the camera focusing screen. Fasten a large piece of mirror (or a negative, glass side out) on the copy so that it just reaches to the edge of the copy.

Have an assistant hold a lamp a few inches from this side of the camera and, without moving the lens front, rack in the camera bellows, then focus the image of the lamp reflected in the mirror. (The copy board itself will then be out of focus.) If the lamp is not in the right position for this, have the assistant slowly move it about until the image is seen on the focusing screen. Having found the position for the lamp, observe the image on the screen and the assistant moving the lamp slowly away at right angles

to the camera until its image moves off the screen. At this point have him move the lamp vertically up and down to make certain that its image cannot be seen on the screen and then have the lamp held in this spot.

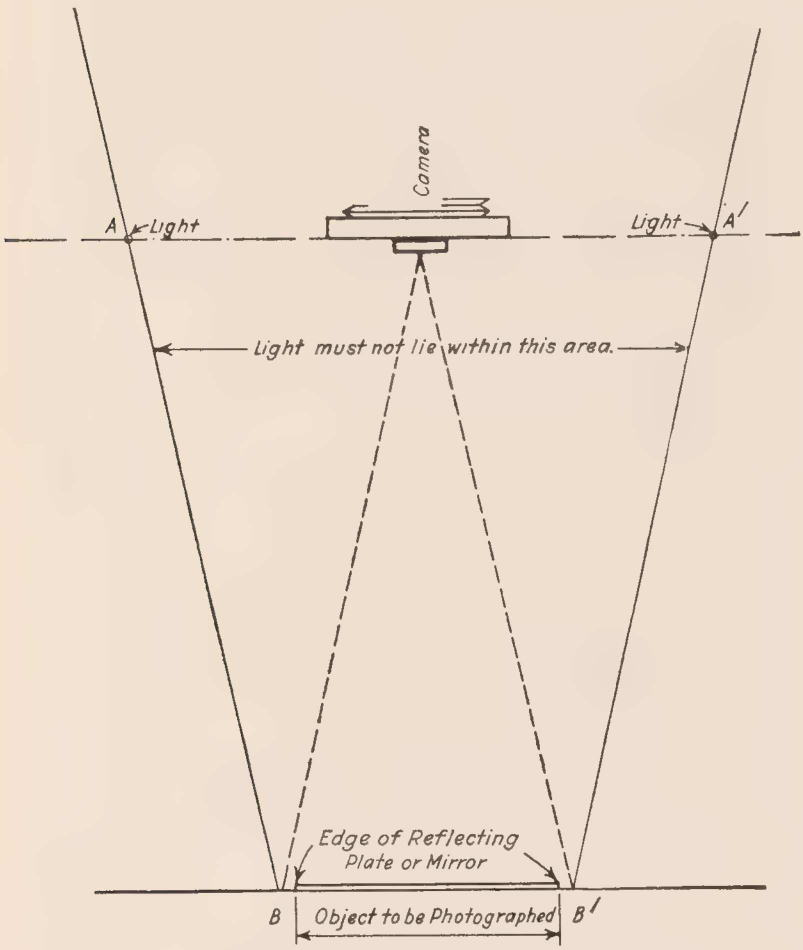


FIG. 44.—DIAGRAM SHOWING HOW REFLECTION IS AVOIDED

Then take a long piece of string, fasten one end to the outside edge of the mirror and stretch it in a straight line out into the room so that the string passes directly over the lamp. This gives the line *AB* in the diagram.

Repeat the performance for the opposite side of the camera and form the line $A'B'$.

The lines $A'B'$ and AB form an angle which must not contain the source of light for illuminating the copy. All bright objects within this angle must either be removed or covered with dark cloths. The camera front itself must, of course, also be in shadow.

Scale.—The size of the reproduction depends upon the distance from the copy board to the lens. As the distance is increased, the size of the reproduction is reduced. In order to reproduce a copy of the same size, this distance will be approximately twice the focal length of the lens. That is, using a lens of 10-in. focal length, the distance from the stop in the lens to the copy will be 20 in., and the distance from the lens to the plate will likewise be 20 in.

Copying to Scale.—Divide the width or height of the copy by the corresponding dimension of the reproduction desired, add 1, and the result will indicate the number of focal lengths required from copy to lens stop.

Thus, if a copy measuring 8×10 is to be reduced to one-half scale or 4 in. on its shorter side and the focal length of the lens is 11 in., then 8 divided by 4 equals 2, plus 1 equals 3, and with a lens of 11-in. focal length the distance from copy to lens stop would be 33 in.

This same rule holds good when copying to an enlarged scale. Thus with a copy 4×5 to be reproduced 6×8, 4 would be divided by 6 giving $\frac{4}{6}$ or $\frac{2}{3}$; adding 1 gives $1\frac{2}{3}$. Then 11 in., the focal length, multiplied by $1\frac{2}{3}$ is $18\frac{1}{3}$ in., the distance required from copy to lens stop.

In order to facilitate the setting of the camera scale, a scale should be marked on the bed of the easel carrier in front of the camera. A mark is first made on the easel bed at a distance of one focal length from the stop of the lens, and this point is marked zero. Then the bed in front of this is divided into distances each of which is equal to one focal length, the points being marked 1, 2, 3, etc., and these distances are divided again into halves and quarters. If the easel is set at any point on the bed, the reduction obtained will be indicated by the number on the scale, so that if it is put at mark "2," for instance, the copy will be made with 2 diameters reduction. If it is put at the mark "$\frac{1}{2}$" the copy will be made with 2 diameters enlargement. At the point 1 the copy will be made full size, and so forth.

When no definite scale for copying is given, the operator may use his judgment as to size and obtain the desired result by moving the copy board backward and forward and measuring the image on the focusing screen, always keeping the image approximately in focus.

Finding the Focal Length.—If the focal length of the lens is not known, place a strip of paper or a rule on the copy board. Set the camera so that, when accurately focused, the image on the focusing screen is the exact size of the strip of paper or rule. Measure carefully the distance from copy to focusing screen. This distance divided by 4 gives the focal length of the lens.

If a print is to be copied to half size, then the reproduction should be one-half the area of the original copy. If copied to half scale, then either dimension of the reproduction must be one-half of the corresponding dimension of the copy. For example, the size of a print measuring 8 × 10 in. is 80 sq. in., and the area of the half-size reproduction would be 40 sq. in., whereas if reduced to half scale the reproduction would be one-half the linear dimension of the copy or 4 × 5 in. and the area would be only 20 sq. in. or one-quarter of the size of the original copy.

Relative Exposures when Copying or Reducing.—The time of exposure varies also with camera extension or distance from lens to plate.

Focusing.—It is important that the reproduction be as sharp as possible. In order to obtain sharpness, it is necessary to focus exactly. If the original is dark and has no well-defined lines to focus on, a sheet of printed matter may be placed temporarily on the face of the copy as an aid in focusing.

Never attempt to focus by moving the copy board or the lens, as the size of the reproduction changes with the distance from the copy board to the lens. If a rapid rectilinear lens is used, it is best to focus on the image at a point about midway between the center and the edge. To obtain the best definition with a lens of this type, a small stop should be used.

Exposure.—The exposure depends upon the following factors:

1. Nature of the original copy (color, brightness).
2. Amount of reduction of enlargement (camera extension).
3. Size of lens aperture.
4. Light intensity.
5. Speed of plate used.

(1) A dark or yellowish copy will require a longer exposure than a bright copy or black and white.
(2) As a copy is enlarged in size, the camera is extended and the brightness of an image projected by a lens varies inversely as the square of the focal length, so the exposure increases as the camera is extended.
(3) When a lens is stopped down a portion of the light is held back.
(4) Accuracy in judging the light intensity will be acquired only through experience.

Trial Exposure.—A practical way of determining the exposure, one which takes into account every factor involved, is to make a series of different exposures on one plate, varying each exposure by at least 50 per cent. After giving the plate a normal development observe the result and make the exposure for the copy accordingly.

Having obtained the correct exposure on one copy, the operator may be guided by this in judging the next, taking into consideration any change in the intensity of the light, also the nature of the copy and change in camera extension.

We will assume that the camera was extended 10 in. and the correct exposure was one second in making the first copy. The second had to be enlarged and the camera was extended to 20 in. If all other conditions were the same, the new exposure would be four seconds.

Development.—Copy negatives are usually developed in a tray, the completion of devlopement being judged by inspection.

Quality.—In some cases the reproduction will be better than the original; for instance, a flat print can be copied, and the contrast in the negative can be increased by proper development, and therefore produce a print that will be more satisfactory than the original.

Density.—The maximum amount of density obtainable on full development of the negative depends upon the exposure. A badly underexposed negative will never give much density, however long the development is prolonged, while an overexposed plate will easily give excessive density.

Contrast.—The contrast grows during development just as the density does. It grows rapidly at first and then more slowly until

finally the negative will not give any more, however long it may be developed.

The final contrast which can be obtained depends upon the kind of plate used. Fast plates are soft working and give little contrast even with extreme development, whereas slow plates (process plates) are hard working and give extreme contrast.

Copying Line Work.—The copying of line work, such as drawings, engravings and documents, demands a different procedure than that followed when gradation of light and shade is desired. For line work the negative must have intensity and contrast. The dark portions of the original, such as the lines of a drawing or the writing of a document, should be represented on the negative by practically transparent "clear glass," as it is called. The highlights, that is, the surface (generally paper on which the drawing is made) must be opaque.

Special plates or film suitable for this work are available. They contain a moderate amount of silver iodide with considerable silver bromide. For this reason a moderate, but not excessive, addition of potassium bromide is made to the developer.

The copy is illuminated in the usual way, i.e., with the light directly in front, so as to avoid shadow effects from the grain of the paper, which lateral lighting will cause. The exposure should be full, but not excessive, and the lens stopped down only enough to cut off oblique rays which will act like diffused light, and thus interfere with the desired result. The stopping should, therefore, be just sufficient to get the parallel rays from the copy.

The Lens.—In conclusion it is well to remember that in order to produce the best result it is necessary to keep the lens free from dust and finger marks, since flat negatives are often produced by this fault.

COPYING A MOSAIC

When the mosaic is larger than 20 × 24 in. (the size of the film used in the copy camera) it will be necessary to copy it in sections unless the scale is to be reduced so that it will go on this size of film.

For example, if the mosaic were 38 × 46 in. and were to be copied to the same scale, the area would be divided into four 20 × 24-in. areas, allowing sufficient overlap. This would be copied on four negatives as follows:

1. Fasten the mosaic to the mosaic holder by means of the

clamps furnished. If these clamps do not hold the mosaic flat, use four 4-in. carpenter's clamps.

2. Check the board to see that it is against the upright supports that hold it. (The camera must be set up so that the axis of the lens is perpendicular to the plane of the mosaic-holder board.)

3. Arrange the lights in such a manner that no reflections from the overlapping prints will show on the ground-glass.

4. Load the film holder. The film should be loaded in the center of the holder so that the proper overlap can be obtained. The glass of the holder should be cleaned before loading.

5. Focus the camera. This is accomplished by turning the hand crank on the base and at the rear of the camera. To place the camera farther from or nearer to the copy, push or pull the camera or its base. When the image is of the correct scale and is sharply focused, lock the camera in and tighten the hand clamp on the base of the camera.

6. Center the lens in the middle of the lens board. This is accomplished by cranks on the right and left of the focusing crank.

7. Make the first copy of the mosaic at any corner in the slide or move the mosaic holder until the area to be copied appears on the ground-glass. The first negative is ready to be exposed. (The exposure time can be obtained by trial, using the 8 × 10-in. adapter.)

8. For the next exposure move the easel laterally 19 in. The third exposure can be made by raising the holder 23 in., and so on until the area is covered.

THE MOSAIC COPYING CAMERA

This camera is mounted on a wooden frame-work that rolls on the tracks of a metal stand. This stand should be mounted on a substantial base (as concrete) so that it will be perpendicular to the mosaic board. The camera has a bellows extension of 52 in. and can be used with a plate or film up to 24 in. square. A process anastigmat *f*. 10 lens of 25-in. focal length is furnished with the camera.

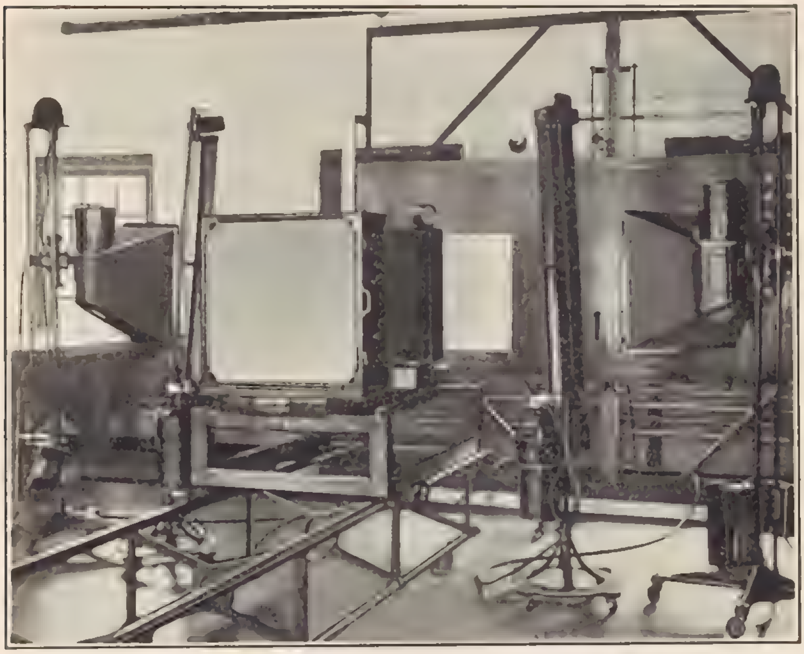
The focusing screen is placed in a wooden frame which can be placed on the back of the camera. The movement of the front of the camera is actuated by the center crank in the end of the wooden frame and the movement of the whole camera is controlled by a

wheel which moves rollers attached to the camera. The film holder is 24 × 24 in. The film is held in the holder by a glass plate.

The dark slide is constructed of laminated wood.

An adapter back is also furnished, permitting film 8 × 10 in. to be used.

The Mosaic Holder.—This consists of a board 10 ft. long and 4 ft. high, balanced by weights.



U. S. Army Air Corps

Fig. 45.—Copying Camera

Mosaic copying board in background with mosaic copying camera in foreground. Vertical lights are Cooper Hewitt mercury lamps and the two lights at left and right are carbon arc lamps.

The board is suspended in a frame resting on rollers attached to a second frame that is fastened to the wall. The board can be raised and moved from side to side. Scales are placed at the bottom and on the left side of the holder. These scales indicate the amount of elevation or side movement of the board. Clamps are furnished to hold the mosaic on the board. These clamps go through perforations on the board. A mosaic $7\frac{1}{2} \times 9\frac{1}{2}$ ft. can be placed on the mosaic holder.

Part III

MAPPING WITH OR FROM THE PHOTOGRAPHS

CHAPTER XIII

THE THREE KINDS OF MAPS

THE method used in constructing a map *with* or *from* aerial photographs will depend upon the accuracy required in the finished product. Aerial photographs can be utilized in constructing a map of any precision. Maps constructed with or by aerial photographs will be considered, for convenience, in three general divisions: the uncontrolled mosaic, the photographic map, and the line map. Each of these three divisions will possess varying degrees of accuracy depending upon the methods and care used in their construction. The latter two will also depend upon the number and accuracy of the control points used.

The Mosaic Map.—The mosaic map is constructed of strips of overlapping vertical photographs taken with a single-lens camera, then laid and pasted on a mount or base with images on each photograph matched as closely as possible with like images contained on the next photograph. In this manner a composite picture is formed of the entire area photographed.

The Photographic Map.—These maps are constructed in practically the same manner as the mosaic map. All prints, however, are projected to a uniform scale, corrected within close limits for all errors and laid on a base on which have been plotted accurately obtained control points. Relative relief obtained either from the photographs themselves or from contours obtained in the field may be drawn on the photographic map.

The Line Maps.—Aerial photographs are used in the compilation of line or hand-drawn maps. They are generally used in the construction of line maps by transferring the desired features contained in the photographs onto tracing paper or linen. By some methods, however, the photographs are taken into the field and contours sketched thereon, the contours and desired features being then transferred to tracing paper or linen. Either the single-lens or multi-lens cameras can be used for this work.

The compilation of line maps by using aerial photographs is a problem which should be treated in a separate volume. The value of such a work could hardly be overestimated. Each year since the world war aerial photographs have increased in value for the map compiler. It is safe to say that aerial photography in its present status is the most valuable aid to map making in general that has been devised in the last century. As improvements are made in methods and equipment, in the manner of taking and using aerial photographs, their value, of course, will increase.

Insofar as the construction of line maps from aerial photographs is concerned there seems to be a great need for a general method which can be applied in constructing the average line map. This would be a basis from which to work. Methods of overcoming the special problems connected with each project could then be applied to the general method.

In Part III the general method for constructing a mosaic is given. Special methods for handling part of the work are also included. By applying the special methods or method in whole, or in part, to the general method, different degrees of accuracy and speed can be obtained. When laying a mosaic map, all available controls should be used even though the map is to be considered an uncontrolled mosaic. The use of these available controls will decrease the amount of work in construction rather than increase it and the use of available controls will make the assembling much easier. When making a map of an area within the United States, a mosaic will seldom, if ever, be constructed entirely without controls, as those controls that have already been located throughout the United States are easily obtainable.

For most projects a photographic map will be compiled. If the flying and photography have been up to standard, there should be very little difficulty encountered in projecting the prints to a uniform scale. This method is always more accurate than when a mosaic is laid to the average scale of the photographs. The latter method, however, is somewhat faster.

It is a quite common practice for the map compiler to construct maps more accurate than can be read by the map user. A map or mosaic should be constructed only with that accuracy which will meet all the requirements of the user. This, of course, applies only when additional accuracy is to be obtained by extra ground work, for example, for obtaining new control points.

If a map is constructed at a scale of 1 : 15,000 the dot of a pencil used when making measurements thereon will cover a representative area of approximately 15 ft. This error will always be included when making measurements of distances on a map of this scale. In addition to this error the shrinkage or expansion of the map, due to atmospheric conditions, may induce an error of 1 part in 500 or more. An accurately constructed map on a scale of 1 : 15,000, therefore, cannot be used and read with the same precision with which it is generally made.

A photographic map constructed of prints which have been brought to a uniform scale, with the errors of tilt corrected by rectifying, and laid out by an expert mosaic compiler, will be accurate in proportion to the number of control points used and the method in which those control points were obtained.

Preparation of the Prints.—When the prints of a project reach the drafting department they are first numbered and then plotted on an index map. This is done regardless of the method of making the map. If a line map is to be constructed from the photographs, after they have been numbered and indexed they are sent together with the index map to the mapping agency or topographer who is to compile the map from them.

Index Map.—After the negatives have been numbered they are plotted on a suitable map, the plottings being numbered to correspond with the number of the respective negative. The map used should, if possible, be a duplicate of the map used on the flight, the scale being large enough to show sufficient detail to make the area covered on each negative easy to identify on the map.

The index map is useful for a number of purposes during the production of a mosaic. This map will show whether or not any parts of the territory to be covered have been missed when photographing and, on a large mapping project, it will serve as a progress map, showing the status of the air work as it progresses. A well-constructed index map is also a great help to the map compiler when making a line map from aerial photographs. It will show the map compiler the photographs that are adjacent in a lateral direction, enabling the section lines under investigation to be rapidly followed. Should a print composing the mosaic under construction be found missing, then by referring to the index map the negative of the desired print can be found without examining all the negatives on the roll.

Fig. 46.—Index Map

Preparation of an Index Map.—The maps best suited for index maps should be on a scale of about 1 : 30,000. First arrange the prints composing the mosaic according to the numbers which have been placed on the negatives. Make a separate pile of prints for each strip of photographs. Pin to the board a number of prints and obtain the average scale of the prints. Then make a templet from a piece of fairly stiff celluloid by cutting a rectangle in it of the average size of the plottings of the prints on the map. In this way the area covered by the aperture in the celluloid, when placed over the representation on the map of the area covered in the print, will represent the approximate ground area covered by the print. Taking the first print of the series of strip *A*, orient the templet on the map so that the aperture in it will cover the map representation of the area shown in the photograph. Then with a pencil trace this area on the map, using the sides of the aperture in the templet to guide the pencil. Place the number of prints in this plotting and continue this process for each print in the series. It will be helpful in orienting the templet to overlap the prints and observe whether the angle that the prints make with one another is similar to those plotted on the map. After all the strips of photographs have been plotted in the manner just described, go over the plotting and its index number with ink using a straight-edge and a ruling pen for this work.

If no map is available, but if control points can be obtained, plot the control points on a suitably sized sheet of paper, using the scale of 1 in. equals 2 miles. If there are several series which join one another, choose first a central series of photographs or one embracing one or more control points near its ends and lay out the photographs on a table or floor so as to overlap as truly as possible. The strip thus formed can then be outlined fairly accurately on the sheet by the control points. Number the strip thus formed at its ends with approximate photograph numbers and if it is a long strip draw intermediate outlines of every fifth or tenth photograph and number them to correspond with the photographs they represent. Lay out along the side of the first series a second series of photographs which adjoin and overlap those of the first series. Trace its position on the index sheet with regard to any control points it embraces, paying attention also to the relation to the photographs of the first series as noted by overlap. Label the second strip in the manner explained for the first strip and then

DIMENSIONS, IN INCHES, OF PLOTTINGS OF PHOTOGRAPHS ON MAPS

(Negative size in each case 7 in.×9 in.)

Altitude, Feet	10-in. Focal Length Lens			12-in. Focal Length Lens			20-in. Focal Length Lens		
	Maps, 1 : 62,500	Maps, 1 : 50,000	Maps, 1 : 20,000	Maps, 1 : 62,500	Maps, 1 : 50,000	Maps, 1 : 20,000	Maps, 1 : 62,500	Maps, 1 : 50,000	Maps, 1 : 20,000
3,000	0.41×0.52	0.50×0.65	1.26×1.62	0.34×0.43	0.42×0.54	1.05×1.35	0.20×0.26	0.25×0.32	0.63×0.81
4,000	0.54×0.69	0.67×0.86	1.68×2.16	0.45×0.52	0.56×0.72	1.40×1.80	0.27×0.34	0.37×0.43	0.84×1.08
5,000	0.62×0.86	0.84×1.08	2.10×2.70	0.56×0.72	0.70×0.90	1.75×2.25	0.36×0.43	0.42×0.54	1.05×1.35
6,000	0.81×1.04	1.01×1.30	2.52×3.24	0.67×0.86	0.84×1.08	2.10×2.70	0.40×0.52	0.50×0.65	1.26×1.62
7,000	0.94×1.21	1.18×1.51	2.94×3.78	0.78×1.01	0.98×1.26	2.45×3.15	0.47×0.60	0.59×0.76	1.47×1.89
8,000	1.08×1.38	1.34×1.73	3.36×4.32	0.90×1.15	1.12×1.44	2.80×3.60	0.54×0.60	0.67×0.86	1.68×2.16
9,000	1.21×1.56	1.51×1.94	3.78×4.86	1.01×1.27	1.26×1.62	3.15×4.05	0.60×0.77	0.76×0.97	1.89×2.43
10,000	1.34×1.73	1.68×2.16	4.20×5.40	1.12×1.44	1.40×1.80	3.50×4.50	0.67×0.86	0.84×1.08	2.10×2.70
11,000	1.48×1.90	1.85×2.38	4.62×5.94	1.23×1.58	1.54×1.98	3.85×4.95	0.74×0.95	0.92×1.19	2.31×2.97
12,000	1.61×2.07	2.02×2.59	5.04×6.48	1.34×1.73	1.68×2.16	4.20×5.40	0.80×1.03	1.01×1.27	2.52×3.24
13,000	1.75×2.25	2.18×2.81	5.46×7.02	1.46×1.87	1.82×2.34	4.55×5.85	0.87×1.12	1.09×1.40	2.73×3.51
14,000	1.88×2.42	2.35×3.02	5.88×7.56	1.57×2.02	1.96×2.52	4.90×6.30	0.94×1.20	1.18×1.51	2.94×3.78
15,000	2.02×2.59	2.52×3.24	6.30×8.10	1.68×2.16	2.10×2.70	5.25×6.75	1.01×1.29	1.26×1.62	3.15×4.05
16,000	2.15×2.77	2.69×3.46	6.75×8.64	1.79×2.30	2.24×2.88	5.60×7.20	1.07×1.38	1.34×1.73	3.36×4.32
17,000	2.29×2.94	2.86×3.67	7.14×9.18	1.90×2.45	2.38×3.06	5.95×7.65	1.14×1.46	1.43×1.84	3.35×4.32
18,000	2.42×3.11	3.02×3.89	7.56×9.72	2.02×2.59	2.52×3.24	6.30×8.10	1.21×1.55	1.51×1.94	3.78×4.86

proceed with the other series, building outward from the first series on both sides.

If neither map nor control points are available, a fair index diagram can be prepared at an approximate suitable scale by building about a central series of photographs. To obtain a reduction ratio make use of available information on the altitude at which the photographs were taken and the focal length of the lens employed. Approximate scales of aerial photographs are obtained from the relation: focal length divided by altitude, both factors being of the same unit.

The Plotting Table.—The plotting table is used for numbering negatives and examining them for the purpose of plotting on maps the areas they embrace and for comparing overlap. The U. S. Army Air Corps uses a plotting table with a plate of glass placed in an opening on top of the table. Under the glass an electric light is placed. At each end of the table there is a container in which the full roll of film and an empty spool can be placed. Each container is equipped with knobs so that after the film has been brought over the top of the table and attached to the empty spool, it can be wound to that spool. A serviceable table can be constructed, to use reflected daylight from a window, by cutting an aperture in the top of the table to insert a plate of glass. A board should be inclined beneath this aperture so as to reflect the light upward. A sheet of white paper pinned to the board will add to the light reflected.

Numbering the Negatives.—After a roll of film has been developed and dried it is placed on the plotting table and each negative is numbered in the lower corner on the emulsion side of the film in reverse figures with india ink. These numbers should be consecutive, corresponding to the exposures in the order in which they were made, and the negatives thus compose one mosaic. For a matter of reference it may be advisable to use a letter to correspond to each roll of film. In addition to the serial numbering other pertinent data, such as the designation of the roll with reference to the whole mission, the day on which the roll was taken, and the names of the personnel engaged in flying and taking the photographs, is often included.

CHAPTER XIV

TYPES OF AERIAL PHOTOGRAPHIC ERRORS

SEVERAL factors are to be taken into consideration when using the vertical photograph as a record of the subjacent terrain. If the aerial photograph is taken at a selected altitude over terrain of equal relief throughout the area covered, and if the photographic plate or film, at the time of exposure, is in a plane parallel to that of the ground over which the photograph is taken, then the result will be the most accurate record that can be obtained of the area covered. A mosaic constructed of vertical photographs taken under the above conditions would be equivalent to a line map in accuracy and in relation of all objects shown on the photograph. The only errors that would be included in a vertical photograph taken under the foregoing conditions would be those of lens distortion, shutter distortion, and shrinkage of the printing paper and film. The magnitude of these distortions is approximately as follows:

Distortion of the field of the lens, 1 part in 1000.
Distortion caused by the shutter, 1 part in 300.
The shrinkage of single-weight paper, 1 part in 400.
The shrinkage of double-weight paper, 1 part in 800.
The shrinkage of the film, 1 part in 600.

These errors are negligible except when doing very large-scale mapping work. A displacement of 3 to 5 ft. can hardly be measured at a scale of 1 : 5,000. It is at about this scale that the limit is reached where these errors may be neglected.

In actual practice, unfortunately, the foregoing ideal conditions do not generally exist and several far more serious errors are involved. The ground over which the photograph is taken usually contains more or less relief, causing a displacement of the images of elevated objects due to perspective. The pilot is often unable to fly the airplane at a uniform height above the ground throughout

the flight. Every change in altitude of the camera at the time of exposure gives the photograph a different scale from the preceding photograph or photographs which were taken at another altitude. The photographic plate or film is not always parallel with the ground when the exposure is made. The camera will sometimes be tilted, causing distortion in the photograph in the form of several different scales being included in that photograph.

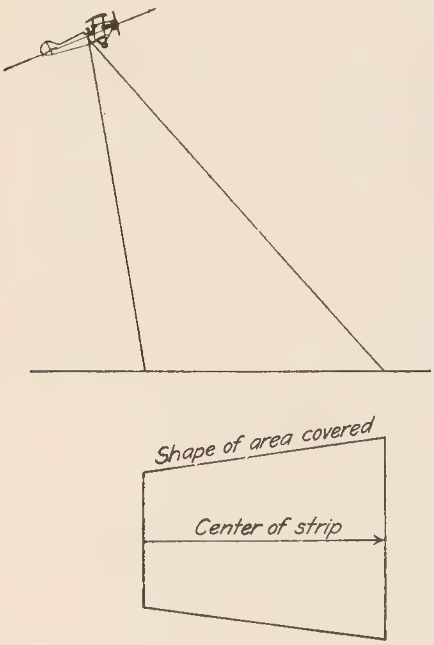


FIG. 47.—AREA COVERED BY A CAMERA WHEN CLIMBING

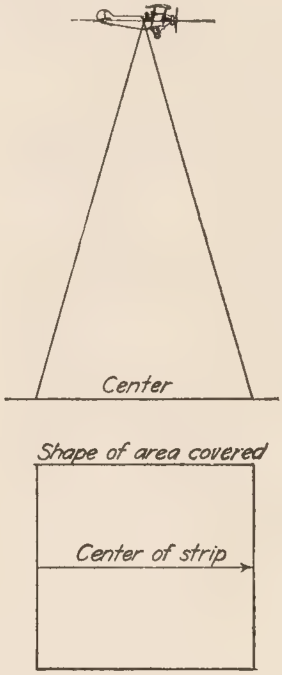


FIG. 48.—AREA COVERED BY A CAMERA WHEN FLYING LEVEL

There are, therefore, three errors that may take a serious amplitude, namely, relief, changes of altitude, and tilt. The errors due to relief and tilt are the most serious, especially when the two errors are combined. The difference in scale, due to change in altitude, can be easily corrected by enlarging or reducing the photograph if no tilt exists in that photograph. If tilt does exist in the photograph to be enlarged, any errors due to tilt will be increased by enlarging.

Tilt.—When a camera is tilted from the vertical at the instant an exposure is made the ground area covered by that photograph

will be distorted in shape and scale. The area covered by a vertical photograph forms a rectangle, whereas the area covered by a

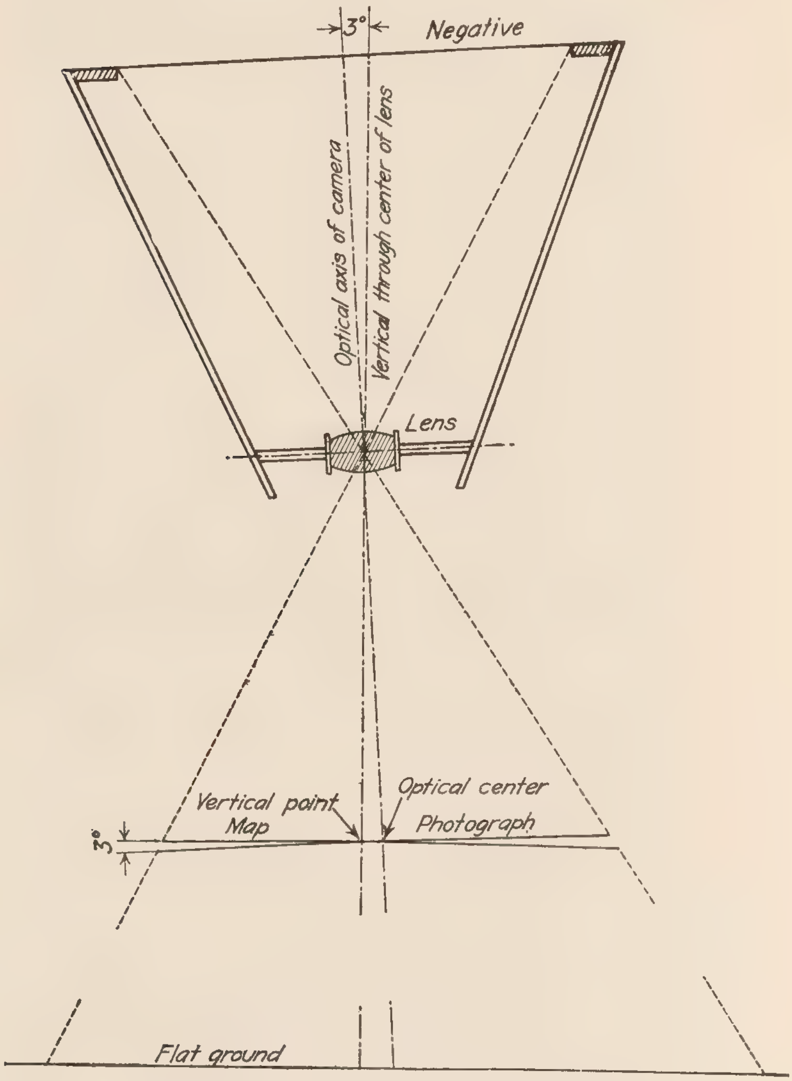


Fig. 49.—Section Showing Camera Tilted

tilted photograph is shortened on one side and lengthened on the other, forming a trapezoid.

When a photograph is tilted slightly (to 3 deg.) the side of the area in the direction of and perpendicular to the tilt will be practically lengthened the same amount as the opposite side of the area is shortened.

The vertical point and the center of the photograph will not coincide when the photograph is tilted. The separation of these points increases as the degree of tilt is increased.

The displacements caused by tilt fall along lines radiating from a point half-way between the vertical point and the center of the photograph. The axis of tilt is considered as a line running through the point half-way between the center and vertical point.

The axis of tilt is perpendicular to the direction of tilt and has the same scale as if the photograph were taken with the camera truly vertical.

Lines parallel to the axis of tilt will each have definite but different scales. Lines other than those parallel to the axis of tilt will have both indefinite and different scales.

The discrepancy in measurement between two points on a tilted photograph will depend upon the angle that a line joining those two points makes with the axis of tilt and the distance the points are from the axis of tilt.

A tilted photograph can be accurately scaled only when the direction and amount of tilt are known. The direction and degree of tilt of the photograph can be shown by the image of the level bubble if the bubble has not been affected by some outside force.

By a comparison of distance between points on the photograph and the true distances between those points on the ground, the direction and degree of tilt can be determined. When a photograph has been tilted 3 deg. the maximum angular derangements, as measured from the axis of tilt, will be approximately $4\frac{1}{2}$ deg.

Figure 50 shows an exaggerated shape of the area on the ground covered by a photograph taken with a camera tilted laterally from the vertical. The line *QR* shows the direction of tilt. The line *AB* is the axis of tilt and has the same scale as if the photograph had been taken with the camera vertical. The lines *GH* and *CD* have definite scales that are shorter than the scale of the line *AB*. The lines *IJ* and *EF* also have definite scales, but are longer than the line *AB*.

The scale of the lines *ST*, *KL*, *MN*, and *OP* is indefinite throughout their entire length. The line *MN* making a greater

angle with IJ than the line KL makes with it will show a greater error than the line KL.

The line OP makes the same angle with IJ as the line KL makes with IJ, but the angle OP will show a greater error than the angle KL as it is farther distant from the line AB.

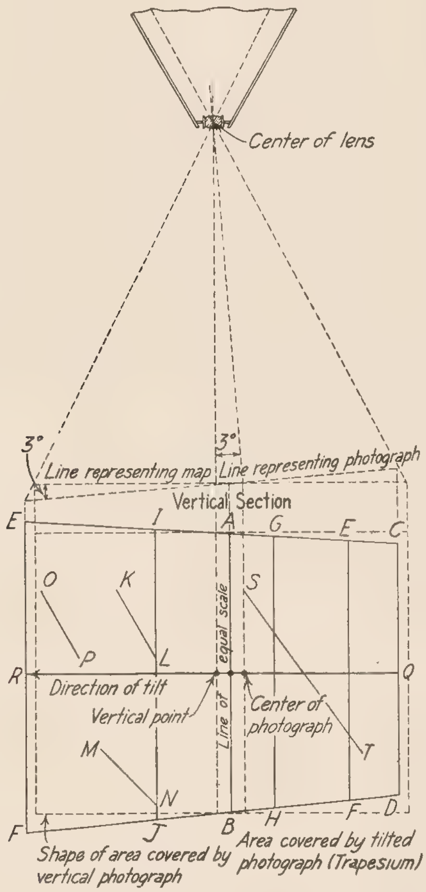


FIG. 50.—RELATION BETWEEN VERTICAL AND TILTED PHOTOGRAPH

The broken lines represent the approximate area that would have been covered if the photograph had been taken with the camera vertical.

Relief.—When an aerial photograph is taken with the camera vertically true, images of objects on a level with the surface will be in practically their correct positions on the photograph. All other images will be displaced on the photographs, due to perspective, except a point directly under the camera which will not be displaced regardless of the elevation of that point.

The displacement of images of elevated objects will fall along lines radiating from the vertical point. The direction of displacement, therefore, will be either toward or away from the vertical point. Images of elevated objects are removed farther from their true position in relation to the vertical point and images of depressions are moved from their true position nearer to the vertical point. The amount of displacement depends upon the distance of an image from the vertical point and the height or depth of the object photographed. The displacement can therefore be measured and

corrected. For example, points 300 ft. high and 5 in. from the center of the photograph will be displaced approximately 60 ft., whereas a point of the same elevation and $1\frac{1}{2}$ in. from the center of the photograph will be displaced approximately 30 ft.

Figure 51 shows the displacements of images of elevated and depressed points on a vertical photograph. The datum plane A is considered as being 200 ft. above sea level. The point B is displaced in the direction BB' as it is higher than the datum plane A. Although the point C has the same elevation as point B, a greater displacement is shown as C is farther distant from A than B is

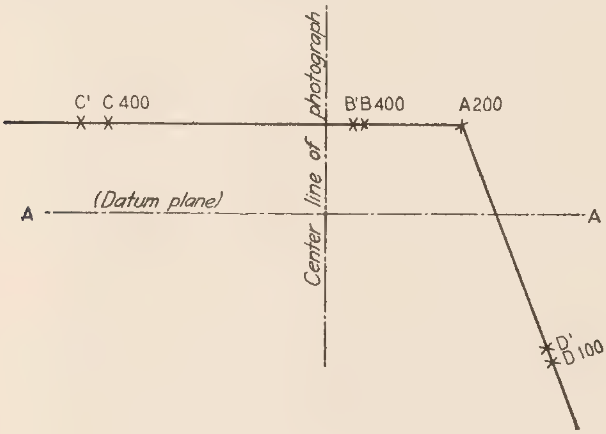


Fig. 51.—Distortions Caused by Relief

from A. The point D is displaced in the direction of D' as it is lower than the datum plane A.

The datum plane does not necessarily have to be considered at A. If the datum plane were 400 ft. the point A—at 200 ft.—would not be displaced as it is in the center of the photograph.

Relief Combined with Tilt.—The problem of solving the errors caused by relief or by tilt when they exist alone is not complex, but the combination of the two errors is so mixed that it complicates the problem to the extent that it is difficult to determine one error from the other. These two errors, however, have one characteristic in common. Distortions caused by relief and tilt radiate from practically the center of the photograph, thus giving a basis for their elimination. The displacements of points caused by relief radiate from the vertical point and those caused by tilt

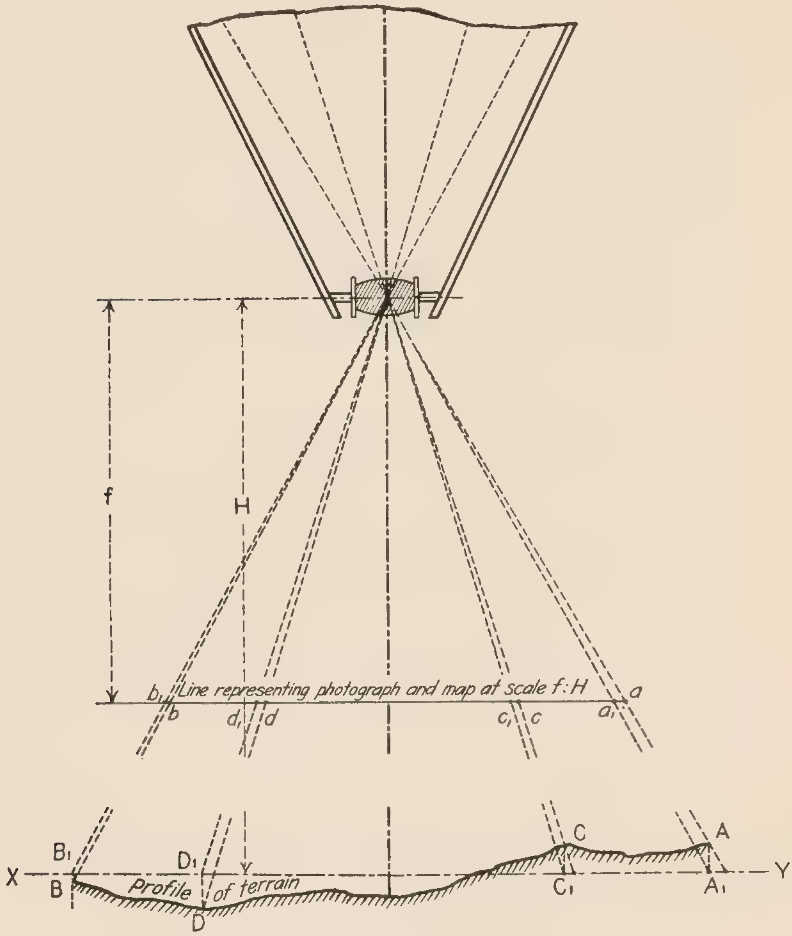


FIG. 52.—EFFECT OF RELIEF

This figure is a vertical section through a camera which has been properly leveled at the time of the exposure.

X-Y is the datum plane to which the map or photograph is referred.

B-A is the profile of the terrain illustrating the relief existing on the ground.

b-a is the line representing the photograph and map at the scale of $\frac{f}{h}$.

The amount of displacement of any chosen point with a given amount of relief is dependent on the distance that point is away from the vertical point. The height of *A* and *C* are assumed to be the same, but since *A* is farther from the center than *C* the displacement of the former is greater.

The displacements fall along lines radiating from the center point, which has no displacement regardless of what its height is.

radiate from a point halfway between the vertical point and the center of the photograph. In a slightly inclined photograph, up to 3 deg., the distance between the vertical point and the center of the photograph is not great.

The Center of the Photograph.—When laying a mosaic, or constructing line maps from vertical photographs, a position near the center of the photograph should generally be the only part used.

All major errors common to vertical photographs increase in proportion with the distance from the center of the photograph.

Even though there may be no discrepancy, due to tilt or relief, the error caused by the curvature of the lens makes it advisable to use, and refer to, the center portion of the photograph.

CHAPTER XV

MAPS AND MAP READINGS

DEFINITIONS

A MAP is the representation on a plane surface of a portion of the earth's surface. Theoretically, the earth is an oblate spheroid, a figure formed by rotating an ellipse around its shorter axis. Because of continents and islands, the actual surface is slightly irregular. Its polar diameter is 7,900 miles, and its equatorial diameter is 7,926 miles. Its axis of rotation is its polar diameter, and the direction of rotation is from west to east. The imaginary intersections of the axis with the earth's surface are called the poles. It so happens that the poles do not move with respect to the earth's surface, but remain fixed. This fact is used as a basis for mapping. Circles on the earth's surface cut by imaginary planes passing through the poles are called meridians of longitude. Circles cut by imaginary planes at right angles to the axis are called parallels of latitude. The parallel midway between the poles is called the equator. The equator divides the earth into the Northern and the Southern Hemisphere.

Latitude and Longitude.—**Latitude** is the number of degrees north or south of the equator, the equator being zero degrees and the poles 90 degrees. Points in the Northern Hemisphere have north latitude; and in the Southern Hemisphere, south latitude. The meridian of longitude through the Greenwich Observatory, London, England, has been adopted as zero degrees of longitude. **Longitude** is measured east or west of this Greenwich Meridian, up to 180 deg. All points in North and South America have west longitude. The difference between latitude and longitude can be remembered from the meaning of the words. Longitude goes to 180 deg. and it is therefore the long east and west dimension, while latitude goes only to 90 deg. and therefore is the width, for that is the meaning of the word.

Scale of Maps.—Every distance on a map must bear a fixed relation to the corresponding distance on the ground. This fixed relation is called the scale. Due to the fact that the rise and fall of the ground cannot be shown on the map except by symbols, distances are always measured and written, except when otherwise stated, as if there were no rise and fall. The vertical distance is called elevation.

Methods of Stating the Scale.—Words and figures are used in expressing scale, such as: 3 in. = 1 mile, indicates that 3 in. on the map equal 1 mile on the ground; 2 in. = 400 ft., indicates that 2 in. on the map equal 400 ft. on the ground. A graphic scale is the symbol drawn on the map, divided into equal parts, each division being marked not with its actual length but with the distance which it represents on the ground. The left unit is generally subdivided into ten equal parts and the zero is at the right of this unit. The graphic scale is the most satisfactory because it always gives a true reading no matter how the map is changed in reproduction or by shrinkage or expansion.

Representative Fraction (**R. F.**).—The R. F. of a map numerator shows the units of distance on the map and the denominator shows the same units of distance on the ground. For example, for $\frac{\text{map}}{\text{ground}}$ the R. F. will be shown on every map thus: Scale $\frac{1}{5{,}000}$. In manuscript it is written 1 : 5,000. A map is said to have a larger scale than another map when the value of its R. F. is greater than the R. F. of the other map.

True North.—Points where the axis intersects the earth's surface are called the North and the South Pole. The shortest line which can be imagined, if drawn on the earth's surface connecting the two poles, would be a meridian and its direction would be termed "true north and south."

Magnetic North.—Near the true North and South Poles are the so-called "magnetic poles." These, unlike the true poles, are not clearly defined and stationary, but cover an area of uncertain extent and move slowly at a variable rate. The ends of a magnetized bar or needle are attracted by the magnetic poles and point in the general direction of those poles. The failure of the needle to point directly to the magnetic poles is caused by the unequal distribution of the earth's magnetism and also by the close proximity of a magnetic body.

Declination.—Due to the differences of position between the true and magnetic poles and the unequal magnetic distribution throughout the earth there will be, except in limited localities, an angle between the true and the magnetic north. This angle is called **declination.** When the needle points east of true north, the declination is east; when west of true north, the declination is west. Points on the earth's surface, where true and magnetic north coincide, may be connected by lines called "agonic" lines. Lines joining points having the same declination are called "isogonic" lines. The declination in any one locality is subject to change, the amount of which can be predicted from past records.

Azimuth.—Azimuth is used for measuring or expressing horizontal angular direction. It is the angle measured clockwise from a base direction line which may be the true meridian, magnetic meridian, or a north and south grid-line. Although generally the zero for azimuth is taken at the North for map reading purposes, it might as logically be taken at the South. Therefore, care should be taken to indicate the direction line and zero by expressing azimuth as follows: Magnetic azimuth, 40 deg. from North; true azimuth, 20 deg. from South, etc. An azimuth designated for use on the ground should be magnetic and it may therefore be read directly from the compass.

Orientation.—A person is said to have oriented himself when he stands on the ground and knows the cardinal directions. A person is oriented with respect to a map when he knows his position on that map, and a map is oriented when the true meridian on the map points along the true meridian through the observer's position on the ground.

Relief.—The variation in height of the earth's surface, as hills, valleys, etc., is termed "relief." Some maps are constructed so as to convey to the map reader a definite conception of the ground's forms. The ability to comprehend relief from the map requires an understanding of the way in which the various ground forms have been produced by nature. A large degree of the regularity and system of the present-day ground forms is due to erosion. Not all the water in heavy rains seeps into the soil. Much of it runs off. At one point a stream begins. As it flows downward it joins others. Soon several unite into a fair-sized creek, which in turn, joining other creeks, forms a river. This

process, having continued for ages, has carved the earth's surface into the form that it has today. Drainage lines of any area, together with ridge lines, form a system of master lines which if understood will make it possible to grasp the main features of topography. Getting the "lay of the land" really consists in studying these master lines. The system that is adopted for showing relief on a map must convey to the reader immediately the conception of the drainage and ridge lines of the system of relief.

Methods of Representation.—As a map is necessarily flat, special conventional signs are necessary to show relief. On modern maps relief is usually indicated by contours.

Contour.—A contour line represents an imaginary line on the ground, every part of which is at the same level with reference to sea level. Such a line can be drawn at any altitude, but in mapping only the contours at regular intervals of altitude are shown. The line of the sea coast is a natural contour, the datum line, or zero of altitude, being mean sea level. For example, a 10-ft. contour would be the shore line if the sea should rise 10 ft. As well as showing altitude, contour lines show the shapes of hills, mountains, and valleys. Successive contour lines that are far apart on a map indicate a gentle slope. Lines that are close together indicate a steep slope. Lines that run together indicate a cliff.

Contour Interval.—The contour interval is the vertical distance in feet between one contour and the next. In showing elevation this information is usually placed at the bottom of the map. This interval differs according to the topography of the area mapped and the scale of the map. In flat country it is usually small; in a mountainous region it may be as great as 250 ft. Certain contour lines are made heavier than others and are accompanied by figures showing altitude. Heights of many points, as road corners, summits, surfaces of lakes, and benchmarks are also given on the map in figures. These figures show altitudes to the nearest foot only.

Depth Curves.—A contour showing points of equal elevation below the level of any body of water is called a depth curve. These curves will show the depths below a certain datum, indicating usually the mean low water for the body of water concerned. The vertical interval is frequently expressed in fathoms (6 ft.).

Geological Survey Maps.—Maps are prepared by the U. S. Geological Survey at various scales.

1. Scale 1 : 2,500,000 (about 40 miles to 1 in.), a wall map 49 × 76 in. coming in two forms: one in blue and black, showing drainage, states, counties, principal cities, and railroads; and one, blue, black, and brown, showing relief in addition to the above features.

2. Scale 1 : 7,000,000 (about 110 miles to 1 in.), 18 × 28 in., in two forms: one in blue and black, showing drainage, states, and principal cities; and one in blue, black and brown, showing, in addition to the above features, relief.

3. Scale 1 : 12,000,000 (about 190 miles to 1 in.), a desk map 11 × 16 in., in black and blue, showing drainage, states, and principal cities.

4. Scale 1 : 16,500,000 (about 260 miles to 1 in.), a desk map $8\frac{1}{2}$ × 12 in., in black and blue, showing drainage, states, and principal cities.

In moderately rolling country the standard system of scales and contour intervals, which will give good declination of the ground and at the same time cartographic clearness, is as follows:

1. 1 : 62,500 vertical interval normally............	20 ft.
2. 1 : 20,000 vertical interval....................	20 ft.
3. 1 : 10,000 vertical interval....................	10 ft.
4. 1 : 5,000 vertical interval.....................	5 ft.

Soil Survey Maps.—These maps are published by the Department of Agriculture on the scale of 1 in. equals 1 mile. They show roads, drainage, towns, and, by symbols and colors, the various classes of soils within the area.

Post Route Maps.—These maps are made by the Post Office Department for the designation of postal routes and are primarily for internal administration in that Department.

Coast and Geodetic Survey Charts.—These charts are intended for the use of navigators on the coast and are published on various scales ranging from 1 : 5,000 to 1 : 40,000 for harbor charts and from 1 : 80,000 to 1 : 100,000 for coast charts. They show the depth of the water, aids to navigation, and a narrow strip of topography from 1 to 5 miles in width along the shores.

Lake Survey Charts.—These charts are intended for the use of navigators on the Great Lakes and adjacent waters and are published on various scales ranging from 1 : 5,000 for small harbors to 1 : 1,200,000 for the general chart of all the lakes. The charts likewise show the depth of the water, aids to navigation, and a narrow strip of topography from 1 to 5 miles in width along the shores.

General Land Office Maps.—Maps of this bureau are comprised of the following: *township plots*, showing land division and area of tracts; *maps of states* having public land, showing land survey lines and United States reservations; *general maps of the United States*, showing sources of obtaining land, civil and public land boundaries, and progress of land surveys.

International Boundary Commission: United States and Canada.—These maps cover a strip of territory from $\frac{1}{2}$ to $2\frac{1}{2}$ miles in width on each side of the boundary line between the United States and Canada, from the Arctic Ocean to Mt. St. Elias, from the Pacific Ocean to Lake Superior, and from the head of the St. Lawrence River to the Atlantic Ocean. From Mt. St. Elias to Cape Muzon the boundary maps include practically all the territory between the boundary line and the Pacific Ocean. The scales used are: 1 : 6,000, 1 : 12,000, 1 : 24,000, 1 : 62,500, and 1 : 250,000, depending on the locality. The contour intervals range from 5 to 250 ft. and the maps are complete in cultural features and relief.

Forest Service Maps.—The U. S. Forest Service prepares maps of areas included within the national forest boundaries and adjacent thereto. The maps are compiled from all sources, governmental and private, supplemented by Forest Service surveys. They are intended primarily for administrative purposes in the U. S. Forest Service. Besides the topography and culture they frequently carry detailed classification of vegetation. The publication scales are: $\frac{1}{4}$ in., $\frac{1}{2}$ in., and 1 in. to the mile.

CHAPTER XVI

RELIEF

Impressions of relative relief can easily be obtained from aerial photographs. No very simple method has been devised, however, by which accurate contour intervals can be obtained from the photographs themselves. In some projects relative relief is more important than the exact height of the relief. There are several elaborate devices with which contours can be drawn with their correct intervals from information obtained from the photographs. These instruments have not proven practicable as yet for ordinary mapping and are not used in this country at this time. These instruments, however, show the possibility of this important feature of aerial photography. Among the outstanding instruments of this type are:

The Stereocomparator.—This instrument was invented and developed by Dr. Pulfrich. This machine puts in contours mechanically.

The Stereoplanigraph.—This instrument was invented by Dr. Bauersfeld. The principal advantage of the apparatus is that it is immaterial how the pictures are taken, that is, either vertical or oblique. Stress is put on the fact that the connection between the drawing pencil with the different movements of the measuring system is not rigid and can be regulated at will. It is also possible to connect the planigraph with a second drawing board so that plans can be worked out simultaneously at different scales. The relation of the scale of the measuring system and that of the drawing one is not rigid but changeable.

The Aerocartograph.[1]—The aerocartograph is a smaller and lighter instrument than its sister machine, the autocartograph. It is used for plotting stereo-photogrammetric pictures with the axis in any direction. The instrument is constructed on the same

[1] For details on the Aerocartograph, see Dr. R. Hugershoff's printed Lecture, of November 25, 1926, "The Aerocartograph."

principle as the autocartograph. The determination of points or continuous plotting of planimetry and contour lines is conducted on the principle of plane table mapping. In this mánner the sight rays are derived from two plates which have received the same orientation to each other and to the horizon which they had at the moment of exposure. Photo-carriers are used instead of the camera. The photo-carriers may be tilted toward each other at any angle and adjusted to the drawing surface whereby special devices restore the abnormal position of the plate with regard to the objective caused by thermic and mechanical influence. The two plates are observed by means of a twin periscope through an objective, the arrangement being optically equivalent to the camera lens used. The necessary revolutions for adjusting the point are so distributed on the photo-carrier and telescope that by turning the photo-carriers about their vertical axis the horizontal components are adjusted, while by revolving a reflector fitted in front of the fixed periscope about its horizontal axis the vertical direction component is set. During this process the binocular eyepiece rigidly maintains its position. The plotting is usually carried out on a flat drawing surface which is part of the apparatus. Thereby the drawing pencil is coupled with the distance slide for horizontal and oblique photographs. The position of the driving spindle permits the pencil to be taken from the distance slide and to be coupled at any desired point with the altitude spindle. By this method not only horizontal and oblique but near vertical and vertical photograms can be worked out on the drawing surface of the autocartograph. In addition to this flat surface, there is a drawing drum upon which all kinds of photograms may be traced in the same or double the scale of the plotting on the flat surface. The instrument may be equipped with a coordinatograph, to be erected at the side, which, coupled with the driving shafts of the aerocartograph, reproduces the latter's movements.

Stereograms.—Relative relief, as stated before, can be obtained by much simpler methods, namely by using the stereoscope. Parallax is the basis on which the stereoscope is constructed. When using the ordinary type of stereoscope the picture must be mounted on a base with the two prints in their proper relation to one another and with distances between images of the same objects on the photographs approximately the distance between the human eyes, for example, $2\frac{3}{4}$ in. A line drawn from the same object on each

photograph must be parallel to the base and the line of flight, the line of flight being an imaginary line drawn on the ground between two positions directly beneath the airplane at the time the exposures were made. The method of mounting stereoscopic prints is as follows:

1. Match the prints so that they overlap in their proper position.
2. Place the straight-edge along the line of flight as determined by the line passing through the centers of both prints.
3. With the prints remaining in this position place the straight-edge at right angles to the lines of flight. The line formed by the edge of the straight-edge, or any other line parallel to it, can be used as a guide for cutting the prints. The line to be cut will generally pass approximately through the center of the overlapping portion of the two prints.
4. Make two pin-holes along the edge of the straight-edge. Being guided by the pin-holes a straight line is then drawn on the back of the prints.
5. In the position the prints were first placed, mark on the back, and in the zone of overlap of each print, "top" and "right" or "left" as the case may be. These marks will later determine the relative position of the prints on the mount.
6. Draw a line on each side parallel to and $1\frac{3}{8}$ in. from the line drawn through the pin-holes on each print.
7. Then trim the prints on the outside line.
8. Paste the prints on the mount in the position as marked. The base of the prints must be parallel to the base of the mount and the line between the prints in the center of the mount.

The Mirror Stereoscope.—This type of stereoscope should be the one used in aerial photographic work. The mirror stereoscope makes it unnecessary to mount or trim the photographs as described above. It also gives room for script on either photograph when they are in place. The photographs are adjusted until the desired stereographic effect is obtained. The prints are held in position with thumb tacks at each corner. By inspecting the photographs in this manner it is quite simple to make comparisons of heights of objects as shown on the photographs. By sketching lines through all points of apparently equal elevation fairly accurate contour lines can be drawn.

The value of an aerial photograph for showing relief depends upon the following factors:

1. The magnifying power of the stereoscope.

2. The stereoptical vision of the operator.
3. The skill of the operator in adjusting the prints.
4. The photographic quality of the prints.
5. The distance which the airplane traveled between exposures (the base).
6. The altitude from which the photograph was taken.

Courtesy Fairchild Aerial Camera Corporation

Fig. 53.—Military Type Stereoscope in Use, Bringing Views into Relief —Reflecting Mirror Type

7. The contrast between views of the same object.
8. The amount of relief.
9. The time of year, day, and hour the photograph was taken.
10. The focal length of the lens used.
11. The scale of the two adjoining prints.

If two or more altitudes are known (vertical controls) it is possible by interpolation to sketch in the contour lines with a regular vertical interval. (A 50-ft. contour interval is about the smallest that should be used.) The magnitude of the stereographic effect is proportional to the length of the base on which the two photographs were taken, the length being the distance the airplane covered between exposures.

To obtain the best results the eyes must be trained, the picture properly lighted and the stereoscope properly focused. The ability to see stereoscopically can usually be acquired with practice. There are a few people, however, for whom it is impossible to see stereoscopically. One of the difficulties encountered is the strain on the eyes when using a stereoscope. If the work is to be rushed it is advisable for operators to work in shifts of comparatively short intervals.

The practical range of magnification of stereoscopes for examining aerial photographs is three and five diameters, the possible magnification depending upon the photographic qualities of the negatives from which the prints to be examined were made.

The base formed by photographs with a 60 per cent overlap is well within the requirements essential to produce satisfactory plastic effects. By careful work and sufficient control, contour intervals with a probable error of about one part in 150 can be drawn on the aerial photographs by using the mirror stereoscope. As stated before, the contour intervals should not be much less than 50 ft.

CHAPTER XVII

CONTROLS

Controls Defined.—Controls may be defined as all data employed in accurately fixing points on which to construct a mosaic or a map. These data are always related to some point located on the earth's surface. Controls to be of any value when constructing a map or mosaic must be accurately located. The accuracy of a mosaic to a great extent, therefore, depends upon the following: the precision with which these points were located on the earth's surface; the precision with which they were plotted on the base where the photographs are to be assembled; the manner in which these control points were spaced in relation to the assembled prints.

The term "control" usually refers to points located by ground survey, but controls are often obtained from the photographs themselves. When a control point is accurately plotted on the base on which the photographs are to be assembled, and when an object on the photograph representing that control point is placed absolutely over that point, then that object on the photograph is accurately located on the base and is also fixed in relation to all other control points plotted on that base. When photographs composing the mosaic are not all of the same scale, there will be a discrepancy of objects appearing in the overlap; but regardless of these discrepancies, when a control point is reached the object representing that control point must be made to fall directly on it. All other prints not located by control points must be adjusted in the best possible manner so as to fit that print. This rule holds true regardless of the method to be used in assembling the prints.

Horizontal control is the horizontal distance between two points on the earth's surface.

Primary control consists of belts of triangulation on accurately measured bases extending across the country from coast to coast

and from the Great Lakes to the Gulf of Mexico. These triangulation belts are tied directly to astronomical positions.

Astronomical positions are determined by the coast and geodetic surveys, astronomical observatories, and others equipped for this work. Astronomical positions are considered the most accurately located positions. These positions are the bases of all horizontal control. Astronomical positions are usually permanently fixed by a concrete pier upon which is a tablet showing the latitude and longitude of that particular point. These positions constitute what is known as the **North American Datum.**

Belts of primary triangulation are connected by belts of triangulation or by lines of traverses of secondary importance, each of which is known as a **secondary control.**

Secondary control is also the term used for controls taken for the photographs themselves.

SOURCES OF CONTROL DATA

Controls are given in two forms: geodetic positions and measured distances between two points. Controls can be obtained from the following sources:

U. S. Geological Survey: The U. S. Geological Survey is the largest maker of topographical maps in this country. This bureau is able to supply a greater amount of survey data than any other mapping agency. Among the reports published by the U. S. Geological Survey is a pamphlet for each state containing the results of triangulation and primary traverse. These bulletins and others will be furnished upon application to the Director of the U. S. Geological Survey, Washington, D. C. They not only include data published by the U. S. Geological Survey, but also include such other authentic survey data as may have been made by the U. S. Coast and Geodetic Survey, Great Lakes Survey, or other agencies. The data in these reports are expressed in terms of latitude and longitude. Data expressed in terms of latitude and longitude are probably easier to plot than data expressed in any other manner.

U. S. Coast and Geodetic Survey: This agency does very accurate surveying and most of the astronomical positions and primary triangulations are established by it. The survey con-

cerns itself with the actual establishment of control points rather than the compilation of data or map making.

U. S. Lake Survey: The controls established by this agency are highly accurate, and most of them are located in states adjacent to the Great Lakes.

U. S. Hydrographic Office: The Hydrographic Office confines its work to surveying the coast lines, lakes, and rivers.

Corps of Engineers, U. S. Army: Maps prepared by the Corps of Engineers usually cover a small area on a large scale and are of very little value for obtaining control points.

Public Land Survey: The main duties of this office are those of sectionizing the country. Township plats may be obtained from this survey which will show all the field notes made in sectionizing townships, the distance between section lines and the azimuth of all lines. Control of this type should be carefully checked before being used, since a great many of these surveys are from fifty to sixty years old.

State, County, and City Surveys: Often very reliable control data can be secured from state, county, or city surveys.

OBTAINING PRIMARY CONTROL DATA

The ground measurements or surveys, from which control data needed in map and mosaic making are obtained, are of different types which vary according to the degree of accuracy sought. An aerial photographic mosaic made of photographs taken over level country may be compared favorably in accuracy with any type of survey except a precision survey. A precision survey is one of a limited area and made as accurate as is humanly and instrumentally possible. With the exception of a precision survey all other kinds of surveys are more or less imperfect and the degree of accuracy often claimed for them is not reducible to map form.

An aerial photographic mosaic, if controlled by such survey data, can for practical purposes be made as accurately as the line-drawn map. The survey data used in mosaic making are usually obtained from the Corps of Engineers, the U. S. Coast and Geodetic Survey, and the U. S. Geological Survey. From such data, including the field notes of fixed positions, it is possible to plot these positions to scale on the mount and, after locating the posi-

tions on the individual photographs, to assemble the photographs so that the points as they appear on the pictures will be exactly over the points as plotted on the mount. If the size of the area is small and there is a quadrangle sheet of U. S. Geological Survey of recent date covering it, then it will be found satisfactory to transfer the control points from such a map by means of the pantograph.

FIELD WORK

Whenever possible the surveyor starts from some known point in the North American traverse, or from a known point of the North American Datum which has been extended by triangulation by the North American traverse. After locating this point accurately, from its description and from the monument or marker on the ground, he sets his transit over the point and sights on some distant point along the outer edge of the area to be surveyed. A transit is an instrument mounted on a tripod with a compass graduated to 360 deg., and a telescopic sighting device. This sight also carries an arc which is used to show the elevation or fall. Having sighted on the object until it appears in the center of the cross hairs in the transit, the surveyor takes a reading from the compass and the bearing of the distant point sighted from the true North. Next, the distance between the known point of the North American Datum and the new point of the survey is accurately measured either by pacing, timing, chaining, or using invartape. The choice of one of these methods depends upon the accuracy which is desired in the traverse. The surveyor then moves to the new station and sets up his instrument at this station, and then sights on a new point on the outer boundary of the survey. The readings and measurements are again made on this new station. The surveyor thus proceeds from station to station around the outer edge of the area being surveyed until he arrives for his last station at the point from which he started or at some other known fixed point. The traverse is then run in the opposite direction back to the initial point.

In an accurate survey two readings are usually taken in one direction, and one reading in the other. The average of these three readings is then computed. Also, at each station the surveyor takes three readings, turning the head of his transit first to the right and then to the left in order that by taking the average

of these readings corrections may be made for any inaccuracy which may exist in the instrument. The location, description, angular reading, and distances between these points is then published in the form of field notes. If the survey is of an extensive territory, astronomical readings are taken in order to check the latitude and longitude of a number of stations.

Triangulation is frequently resorted to on extensive surveys. This method starts from a base line, the exact linear distance of which is known. A survey instrument is set up at each end of the line and an angular reading taken on some distant point. Knowing the exact length of the base line of the triangle and the two base angles, it is possible to determine accurately by mathematics the apex of the triangle and the distance on each leg to the new point, which is the apex. The points located by these methods have a definite and fixed position on the surface of the earth and in accurate surveys they are reduced to positions of latitude and longitude. They are the positions that are used for control purposes and it is therefore apparent that this control is accurate because the positions are plotted to scale on projections that have been previously located accurately on the earth's surface.

CHAPTER XVIII

ASSEMBLING THE MOSAIC

Scaling the Prints.—If the mosaic is to be assembled with reference to the ground measurements or control points so that it will have a uniform scale, it is necessary that the average scale of the prints be determined in order that the control points may be plotted to this scale on the mount. Altimeters (see "*Instruments*") are not sufficiently sensitive to record the exact altitude. It is therefore difficult to maintain a uniform altitude by guidance of this instrument, with the result that there are variations in the scale of photographs even when these are made over small areas. If these instruments were accurate it is doubtful whether meterological conditions would always permit maintaining the airplane at a constant elevation during a photographic mission. The airplane also has a constant roll incident to its flight through the air. Although these changes in altitude, with reasonably good flying, should not be great, even slight changes, as small as 50 to 100 ft., will produce corresponding variations in the scale of the photographs. It is not infrequent, therefore, to find that the scale of one photograph will be different from that of an adjacent exposure. If the difference in scale of photographs composing a mosaic is not great the average scale may be adopted as the scale of the mosaic. If, however, a wide variation is found in certain photographs, and if they are appreciable in number, it will be necessary to enlarge or reduce such negatives as are greatly out of scale in order to bring them to the average scale of the majority of the negatives.

To determine the average scale of the photographs the three methods in general use are as follows:

1. If several distances between different points on the ground throughout the area are known, and if these points can be easily distinguished in the photographs, then measure the distance between these points as shown in the photograph. The scale of the picture can then be determined by the proportion existing

between the image of the distance on the photograph and the actual distance on the ground. Thus, any distance at a known scale is to the same distance at an unknown scale as the first distance is to the second distance, and the first scale is to the second scale. The formula is, therefore:

$$d : D :: s : S. \quad \text{or} \quad \frac{d}{D} = \frac{s}{S}.$$

Knowing the two distances and the scale of one distance, the scale of the other distances can be found. Knowing the two scales and one distance, the distance of the second scale can be found. If a distance on a print is 2 in. and the distance on the enlargement is 4 in. and the scale of a print is $\frac{1}{10{,}000}$, substituting in the formula—

$$2 : 4 :: \frac{1}{10{,}000} : \frac{1}{S} \quad \text{or} \quad \frac{2}{4} = \frac{\frac{1}{10{,}000}}{\frac{1}{S}}$$

and, solving the problem,

$$S = \frac{1}{5{,}000}.$$

If a distance on a print is 5 in. and the scale of the print is 1 : 20,000 and the scale of an enlargement is 1 : 10,000, substituting in the formula,

$$5 : D :: \frac{1}{20{,}000} : \frac{1}{10{,}000} \quad \text{or} \quad \frac{5}{D} = \frac{\frac{1}{20{,}000}}{\frac{1}{10{,}000}},$$

and solving the equation, the distance on the enlargement is 10 in.

This method is satisfactory only when the prints cover a small area. When making the ground measurements, the corners of permanent buildings, fences, intersections of roads, and similar ground objects that are well identified on the photographs should be selected as points for measurements.

2. A measurement of known distances between two points on the ground is used in the second method for determining the average scale of the photographs. If survey notes are available for the area mapped they can be used to obtain accurate distances

between the ground points. Two of these points should be selected that are so located that the distance between them will cover diagonally all of the strips flown in photographing the area. The reason for using two points so located is that one strip may have a fairly constant scale whereas the adjacent strips may vary in scale. Also, it is possible that there will be considerable variation between the first and last strips flown, due to changes in meterological conditions or possibly due to changes in the elevation of the area mapped. The prints included between two known control points should be assembled and matched as accurately as possible. When this assembly has been completed the distance on the surface of the prints is measured between the two selected points. The ratio between this distance and the known distance on the ground will give the average scale of the prints. If two points in a diagonal position, covering at least the majority of the strips composing the mosaic, are not available the procedure outlined above should be repeated for each strip and the average scale thus obtained adopted for the average scale for the assembly.

3. By this method a distance on the surface of the earth is determined as well as a distance on the surface of the prints by the true latitude and longitude of two positions in connection with the tables published in Bulletin 650 of the U. S. Geological Survey. Obtaining the scale from this point is a problem in square root. Having ascertained the latitude and longitude of two points, the true linear footage of two legs of a right triangle is known from the value of degrees, minutes, and seconds as given in the afore-mentioned Bulletin. When obtained, these distances are squared, added together and the square root extracted. The result is the length of the hypotenuse of the triangle or the distance between the points desired. For example, if the latitude and longitude of the stations selected are:

Station 1:
 Latitude 40 deg. 20 min. 15 sec.
 Longitude 80 deg. 10 min. 20 sec.

Station 2:
 Latitude 40 deg. 10 min. 10 sec.
 Longitude 80 deg. 5 min. 0 sec.

when the difference in latitude is subtracted it will be found to be 605 seconds and in longitude 320 sec. Taking the mean lat-

itude at the nearest minute, which would be 40 deg. 15 min., refer to the desired table in Bulletin 650 and find the value of one second of latitude and one second of longitude for 40 deg. 15 min. Multiply these values by 605 and 320, respectively, which are the differences in latitude and longitude. The result will be the value in feet for the difference in latitude and of longitude. In other words this will be the two legs of the triangle. Square these and add, then extract the square root of the result, which is the value of the hypotenuse or the distance in feet between Stations 1 and 2. Assemble the prints as in the second method and measure the distance between these two stations on the prints themselves. The ratio between the distance on the prints and the distance on the ground will give the scale of the prints. In this method the stations selected should intersect diagonally as many strips as possible. Should stations of this kind not be found, select some other station and the average of the scales thus obtained can be used as the average scale of the assembly.

Mounts for a Mosaic.—The material used for mounting a mosaic should have a surface with sufficient tooth for satisfactory adhesion for the prints. The material of which it is constructed should not readily shrink with atmospheric changes and should permit drawing on its surface and similar work connected with the preparation for assembling the mosaic. If the mosaic is to be small, ordinary wallboard, strawboard, or bristolboard of good quality, if not too rough or smooth, can be used. If the surface is too smooth the prints will not readily adhere to it. For trial or practice purposes a good grade of drawing paper which has been shrunk can be used by pasting the margins of the paper to wall board. The paper may be cut from the board and the board used again. When it is desired to make a permanent mosaic, or a high degree of accuracy is sought in the assembly, some rigid substance should be used as a mount, as laminated wood of at least 4-ply, sheet zinc, or sheet slate, unglazed. A composition board known as Vehisote board has proven satisfactory. It has the advantage of being light and it is possible to wash prints readily from its surface. Laminated wood, however, is probably the best support for a mosaic which is to be preserved permanently. Laminated wood may be sawed to any desired shape or size before or after the assembly of the prints. A number of such boards may be closely fitted together and when making the assembly the prints can be

pasted over the seams. If the mosaic, however, is just a step in making photographic copies of a mosaic, the zinc, slate, or Vehisote board is recommended, as the prints may be soaked from the surface after the copy has been made and the mount used for future assemblies.

The size of the mount usually used is 38 × 46 in. A larger board will be inconvenient to handle and will present greater difficulties when the mosaic is copied. A board of the size given can be easily handled. If a number of such boards are necessary for the mosaic, duplicate prints can be assembled on the edges of the adjacent boards, thus providing the necessary overlap.

Preparation of the Mount.—When a mosaic is to be assembled on a uniform scale, the next preparation, after scaling the prints, is to prepare a guide on the mount for assembling and pasting the prints. This control, or guide, may be transferred to the mount directly from a map by using a pantograph, or it may be placed directly on the mount from the survey data that are to be used. Ordinarily, a projection of some type, usually a polyconic projection, is first laid on the mount and the survey data plotted directly on the mount according to the projection.

Using a Map.—When an accurate map exists of the territory of which a mosaic is about to be assembled, the control or guide to be placed on the mount may be transferred directly from the map by using a pantograph. An accurate mosaic, however, will be produced only if the map used is of recent date and has been well controlled. The big objection to this method is that any inaccuracies within the map will be transferred to the mosaic.

By Using Survey Data.—To avoid the errors which may exist in a map the control or guide for the assembly of the mosaic is placed on the mount directly from the survey data. To draw this guide properly on the mount, the operator must have a comprehensive understanding of the elementary principles of map making. Especially he should understand clearly what a map is, what is meant by control in map making, the types and kinds of surveys, the definition of latitude and longitude, and some common systems of projections used in map making, and the method of making a projection and of plotting control data thereon.

Projections.—Control data when obtained from various sources are usually plotted as accurately as possible on some form of projection so that by ordinary map-making methods other data may

be drawn in between these fixed positions, and by photographic methods the prints may be assembled in regard to the control.

Projections are intended to represent the earth's surface with the greatest possible accuracy. They exist in several forms. Each of these projections within its limits has a high degree of accuracy. As a map or mosaic representing the earth's surface is necessarily constructed on a flat medium, some difficulty is encountered in reproducing the curve of the earth on such a medium. All projections that take into consideration the shape of the earth are designed so that the surface of the earth can be represented on a plane surface with the least distortion. It would be a simple matter if the meridians and parallels could be accurately represented on a flat surface, as parallels and meridians would always tend to act as markers and usually localize any error that might otherwise appear if no system were used. All projection systems are designed to represent parallels and meridians as accurately as possible within their limits.

Plane Projection.—The plane projection is satisfactory only when a limited area is to be projected. If at some intersection of a meridian and a parallel, a flat surface were held up to the earth's tangent, the meridian and parallel could be projected on this plane surface as straight lines at right angles to each other. Meridians and parallels that are adjacent to the point of tangency could then also be projected. When the point of tangency, however, is departed from, distortion in the true distances will be introduced due to the curvatures of the earth. In other words, all meridians and parallels would be projected as straight lines, whereas they are in reality curved lines. Plane projection, therefore, can only be used for very small areas.

Polyconic Projection.—Polyconic projection is based on the principle that when a number of cones are placed tangent to some parallel with their apex falling over the pole, the data at the point of tangency, and for some distance on each side of the point of tangency, can be projected on the cone. Any number of these cones can be applied at different adjacent parallels and the data thus obtained when the cones are cut from the base to the apex can then be plotted on a sheet of paper. The intermediate distortion between the points of application of the cones may thus be adjusted with minimum error. In this manner any distortion can be corrected each time a new cone is applied. As these cones are applied,

one for every degree of latitude or longitude, the error may be reduced to minimum, with the result that the projection may be used with accuracy for large areas.

All mathematical calculations required when laying down polyconic projection may be obtained from Bulletin 650 published by the U. S. Geological Survey. This Bulletin covers all necessary data for the entire United States. By using this publication a polyconic projection may be drawn by any draftsman. This Bulletin contains tables giving the value of latitude or longitude in inches and at various scales for any locality in the United States. The necessary offsets for meridians or parallels for any desired number of minutes are also given. By using this information, the correct curvature of the meridians and parallels can be maintained at any scale.

To assemble a mosaic by a polyconic projection and the survey data or field notes, the projection can be drawn either at the average scale of the prints to be assembled or at some convenient scale for the whole area to be mapped and later transferred by pantograph to the various assembly boards at the average scale of the prints. The prints are then assembled so that the points on the photographs, representing positions of known latitude and longitude, as plotted on the board, are superimposed on these positions. By this method, any error which may be introduced into the assembly due to inaccurate matching, distortion of the prints, or otherwise, will be checked each time a station of latitude or longitude is reached, since the point in the pantograph, if superimposed on the point plotted on the polyconic projection, must be accurate, assuming the projection is true, and at the same scale as the photographs.

When laying a polyconic projection, the construction will proceed as follows:

1. Find the central parallel and meridian of the area of which the projection is to be drawn. Then refer to the table in Bulletin 650 for the desired scale and lay off accurately the necessary distances given in the table. For this work polyconic projections are drawn with parallels and meridians plotted at 1-minute or 30-second intervals in order that the latitudinal and longitudinal coordinates or points may be more accurate. Not more than one second of error should result if the positions are plotted with an average degree of skill.

2. Draw two lines at right angles to each other through the center of the mosaic mount, then by referring to Bulletin 650, the value of inches for a minute of latitude or longitude of the area of which the projection is being made can be obtained at the desired scale. One-half of these distances should then be laid off on each side of the two lines drawn through the center of the board. By using the entire distance that can be set off on a beam compass, other degrees of latitude and longitude are plotted to the right and left of the 2-deg. intervals already plotted. To minimize the error in the center of the projection the degree interval is halved in the first case.

3. By reference to the table, the required offset can be obtained at the scale for each minute that the central parallel is departed from. These distances are then plotted, north or south as the case may be. (In the United States they will always be north.) The curved line representing the parallel is then drawn. This line should pass through the point of intersection of the two original lines drawn on the board and will be tangent to each of the distances laid off from the prime parallel.

4. Referring again to the table in Bulletin 650, the required distances for the curvature of the meridians are laid off from south to north along each construction line for meridians.[1]

5. Each line representing latitude or longitude should be numbered and lettered. The style of the letters and figures should conform with those in general use with map-making agencies.

6. Control points are plotted on polyconic projections by one of several methods, which are in general use. A common method is as follows:

Bi-Templet.—After the polyconic projection has been divided into rectangles of 1 minute or a fraction thereof, cut a templet which is equal to the sides of the smallest rectangle. These sides are then divided into equal parts or seconds and, by placing the templet in the proper rectangle, the correct point may be indicated at a corner of the templet by moving the templet back and forth until the required added seconds north and west are lined up with the border lines of the small quadrangle.

Assembling the Prints.—The act of assembling prints is sometimes called laying or building the mosaic. It consists of

[1] For small mosaics under 15 min. of latitude and longitude the data obtained from Bulletin 650 can be plotted in the form of a plane projection.

pasting the photographs in mosaic form to the mount. The operations involved are performed in the following sequence:

1. Selecting the first print.
2. Cutting and tearing the print.
3. Applying the adhesive.
4. Affixing the first print.
5. Repeating the foregoing operations for subsequent prints.

During the explanation of these foregoing operations it is assumed that the prints have been scaled or brought to one scale and that the mount has been prepared with the control data or guide for assembling the prints.

Selection of the First Print.—When deciding which print should be affixed to the mount first, the selection should be made of one covering any portion of the area which contains two or more control points. The first photograph laid down should show such points in order that the subsequent prints may be properly oriented. If two control points do not appear on any single print, in order to obtain the correct orientation, the prints between two control points should be matched together. This matching is done by overlapping the prints so as to form a composite picture with the images common to two points in register. The prints are held temporarily by thumb tacks in this position, until the adhesive is applied and they can be affixed to the mount.

Cutting and Tearing the Print.—Before attempting to tear or cut a print, the operator should examine carefully all surrounding prints in order that the print about to be torn will be divided in such a way as to retain the best definition, color match and accuracy. When tearing or cutting a print to the desired size, there are two methods that may be used.

First Method.—Hold the print between the thumb and forefinger at a point where it is decided to tear it. Then turn it face down and by a continuous upward gentle pull on the remaining portion of the photograph, the emulsion will separate at the division desired and the paper support will tear so as to taper or bevel it, that is, it will leave an edge gradually increasing in thickness from the thinnest layer at its point of contact with the emulsion extending back to the full thickness of the paper. This edge is termed **feather edge.** A print may be torn to follow any desired direction by varying the direction of pull.

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Fig. 54.—A Vertical Photograph Used in Construction of Aerial Mosaic Map

Second Method.—Cut with a safety-razor blade held at a slight angle and using just sufficient pressure to cut through the emulsion on the line at which it is desired to divide the print. Then tear the print as described in the first method.

After a print has been torn by either of the two methods it is advisable to remove any roughness of the edges with the safety-razor blade or a fine piece of sandpaper. A thinner feather edge

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FIG. 55.—LAYING A MOSAIC

should not be attempted by scraping with either the razor blade or the sandpaper. Feather edging a print will make it adhere to the mount much better. Feather edging will also make the junctions of the prints contained in the mosaic much smoother and it will therefore copy much better.

After cutting and tearing the first print, it is best, when possible, to cut the remaining prints along a road, fence line, or a wooded area. When tearing a print through woods where no mark of definition occurs, the print should be torn in a jagged manner so

that a straight tear will not be visible, and the match in the prints will not be apparent.

Affixing the First Print.—Whenever a control point occurs within the area of the photograph affixed to the mount, the mosaic control point indicator should be used in order that the control point on the print may be placed accurately above the control point on the mount. This indicator is essentially a movable arm with a needle point which may be raised or lowered as desired. By swinging the arm the needle point is placed on the control point on the mount, the needle is then raised, and the print placed under it and on the mount, and the needle again lowered and the print moved until the control point on the print rests directly under the needle. This same procedure should be done over all control points on that picture. In this position the first print is then affixed to the mount.

Affixing Subsequent Prints.—After the first print has been affixed to the mount, the subsequent prints are matched to this first print as closely as possible from the details contained in the print. In laying the photographs down, one on top of the other, they should be matched by points along the course line and not by points across the zone of overlap. It is not so easy to match them longitudinally as to match them laterally, but good work requires that they be brought together by points along the course. When the second print is to be laid down, two points on the first photograph, which lie along the course and are common to the second photograph, should be located. One of the points should fall near the border of the first photograph and one near the border of the second photograph. Place the straight-edge along the two points of the first photograph and draw a line on the mount to extend a few inches beyond the space that will be covered by the second photograph. With dividers, compare the distance between the two points as taken from each photograph. If they are practically the same, no longitudinal adjustment will be required, but if they differ it will be necessary to make an adjustment. This can best be done by dotting a mean position for the point near the border to be used instead of the point itself when the photograph is laid down. Then place the straight-edge along the two points of the second photograph and draw a short line at the outer border. Put the first photograph over the second photograph by pricking the point with a pin near the border. Then set the pin on the corresponding point

of the first photograph, swinging the second photograph about the pin until the line at the border falls on the line of the mounting. Paste it down in this position.

Proceed in the same manner with the succeeding photographs. The pin may be dispensed with by trimming the second photograph at the border point. The assembly of prints is thus continued until another control point is reached. At this control point, the corresponding point on the photograph should be made to fall directly over it.

When there is considerable distance between primary control points, secondary control can probably be obtained from the prints themselves. For example, if a road is found to run straight on a single print it can be expected that this road will continue to run straight until a curve or bend appears in it on some other print. Therefore, after the first print showing the road as straight has been placed on the mount the road may be projected on the mount by using a straight-edge. This projected line may then be used as a guide for other prints showing the same road until such time as a turn in the road is observed. This will tend to eliminate swings and errors in matching two prints. Railroads, property lines, etc., also may be used as secondary control points.

When prints are assembled to the average scale of a large number of prints rather than brought to a uniform scale by using the restitutional printer, it may be frequently necessary to stretch some individual print or prints to insure a good match. At times this is permissible if not carried to excess. If it is found that a large number of the prints in assembling require stretching, it is evident that an error has been made in scaling the prints or in the scale of the projection. There is no method of shrinking prints that are too large to match well with a print already laid down. A print, however, can be slightly contracted by dampening it and drying it rapidly. When the mosaic has been matched by this method no effort has been made to correct for tilt.

During the process of assembly care should be taken that the adhesive does not adhere to the surface of the print. It will not only ruin the appearance of that print but will interfere with making a good copy.

Gum arabic may be rubbed off with cotton dampened in water or in alcohol. If the print has been attached to the mount for some time, alcohol is best, as it will dry more rapidly, thus

preventing the print from swelling from the mount. Rubber cement may be rubbed off with the fingers immediately after the print has been affixed to the mount.

When all prints have been assembled it is well to go over the surface with a tuft of cotton which has been dampened in alcohol. Care should be exercised, however, that the edges and corners of the prints are not curled while cleaning their surfaces.

The foregoing method for assembling aerial photographs in the form of a mosaic is intended only to serve as an explanation of the general routine to be followed. There are several other methods which may be used, some of which have greater accuracy. The method selected will depend upon the required accuracy of the finished mosaic. Most of the methods for assembling aerial photographs that are in general use can be applied to the general plan as the one above outlined.

Adhesives.—There are two kinds of adhesives in common use for mosaic assembling, gum arabic and rubber cement.

Gum Arabic.—Gum arabic is an excellent adhesive. If it is desired, however, that the mosaic remain permanently assembled, the gum arabic should be used and the mosaic coated with a protective varnish to keep away the moisture. Unless the finished mosaic is treated in this manner, the prints will have a tendency to loosen at their edges. The special advantage in using gum arabic for mosaic assembly is that the print, after being placed in approximate position on the mount, can be moved slightly in any direction before it sticks fast. The operator is permitted in this way to adjust the print so as to bring it into exact position. The disadvantage of gum arabic is that it will, due to the water that it contains, cause the print to expand, and therefore allowance must be made for this expansion when constructing and plotting the projection and control data. The most satisfactory method of doing this is to determine from the prints their scale and the corresponding scale for constructing the projection, and then to plot the control points.

Rubber Cement.—Rubber cement consists of pure rubber dissolved in benzol. The advantage of rubber cement for mosaic assembly is that the cement does not expand the prints or the mount as is the case when gum arabic is used. The disadvantage of the cement is such that as soon as any portion of the print comes in contact with the mount, the print cannot be moved without

injury. Skill, therefore, is necessary when using this adhesive in order that the prints may be laid exactly in their correct positions.

The Application of Gum Arabic.—When gum arabic is used the mosaic compiler must be sure that it is reasonably fresh and of the proper consistency. It should be a thick liquid that will pour readily and not congeal into a jelly. The print to be mounted is placed face down on a suitable board or pad and a small quantity of the mucilage is brushed over the back of the print. This is rubbed well into the paper backing with the fingers, especially into the feather edges to insure that the print will adhere firmly to the mount without a tendency to curl. The surplus mucilage is then removed from the back of the print with the hand. The print will then be slightly moist and sticky. In this condition, it is placed on the mount in its proper position and gone over with a piece of damp absorbent cotton in order to remove all air bubbles and squeeze out the surplus mucilage. The rubbing should be continued until the print is thoroughly dry and care should be taken to insure the firm adhesion of the edges to the mount. As gum arabic dries along the edges there is a tendency for it to crystallize and push up the edges of the print. This may be avoided by working down the edges of the print with the fingers until the print is thoroughly dry.

Application of Rubber Cement.—When rubber cement is used as the adhesive, the area to be covered by the print on the mount must first be covered with a light coating of the cement. The back of the print is then also coated with the cement. The cement should be rubbed well into the corners and feather edges before proceeding to fully cover the back of the print. The cement should be rubbed in as well as it will permit. As the cement dries very fast there is a tendency for it to roll into small balls of rubber. This should be guarded against, as these rolls cause humps in the print when it is placed on the mount. The cement should therefore be rubbed in until it becomes so sticky that further rubbing is impossible. Both mount and print should then be allowed to dry. When the print is dry the surface of the cement will lose its gloss.

Under ideal conditions the drying will require about fifteen minutes. There is no danger that an application of rubber cement on the print or mount will become too dry, but care should be taken that the print is dry enough as it will not adhere firmly to the mount

unless both print and mount are dry. The print is then held in its position over the mount, with exercise of care to place the print absolutely in its correct position, for, as previously stated, once the print touches the mount it cannot be moved again. A dry piece of absorbent cotton should be used in smoothing the print and working down all the edges. The smoothing should be done in one direction in order not to cause bulges in the prints. Water should not be used because moisture will lessen the adhesive effect of rubber cement. Once the prints are dry, moisture will have no effect.

Titling and Finishing the Mosaic.—After the mosaic has been cleaned a border is ordinarily added so as to form a clean rectangular figure and thus improve the appearance of the work. The border should be applied so as not to cover any of the important features of the mosaic. After the border has been completed the title for the mosaic should next be lettered. The style of letters used should correspond as closely as possible to that used on maps. The title may be drawn on the scale of the mosaic or it may be drawn on some convenient larger scale and then copied down to the scale of the mosaic. It is recommended that the title be drawn on a larger scale and then reduced to the scale of the mosaic. In this way the letters due to reduction will lose some of the pen marks and will appear much neater. Certain pertinent information should also be included in the title. The title usually includes the words, "An Aerial Mosaic," "A Photographic Map" or "A Mosaic." The title usually indicates also the area included by the mosaic, and the state in which the area is located, the latitude and longitude of the southeast corner of the area, and the average scale of the mosaic. The title should always include a visual scale of the mosaic, that is, a line graduated to represent the value of the mosaic corresponding to distances on the ground. This visual scale should be drawn so that it will be true when the title is reduced, that is, when the title is applied to the mosaic the values as shown on the graphic scale should be true for the mosaic. Likewise, if the average scale of the mosaic is shown it should be true for the scale at which the copy of the mosaic is to be reproduced.

The title of a mosaic is usually placed in the southeast corner, but if this position covers any important information any other convenient place may be used. Nothing detracts so much from a mosaic as a poorly made title; great care accordingly should be

exercised. The casual observer will often attempt to judge the accuracy of the work by the appearance of its title.

The Pantograph.—The pantograph is a drawing instrument used ordinarily to transfer data on one scale from a map or some other sheet containing control points to drawing paper or a mount on another desired scale. In principle this instrument is a flexible parallelogram. Since the angles are joined so as to be flexible, the sides of the parallelogram remain parallel regardless of the horizontal position in which the instrument may be placed.

The process of transfer, therefore, is reduced to a proportion between the distances on two sides of the parallelogram of these sides extended. If the correct proportion is adjusted by the pointers on these two sides, as may be done by setting all movable parts at the same point on the graduated scales on the arms, data copied under one pointer will be produced, under the other pointer, parallel and proportionate to the original data.

The so-called precision pantograph is probably the most accurate of several forms in use. This pantograph is of a steel arm suspension type and is made with arms of various lengths. The longer the arms, the more accurate will be the data transferred by this pantograph. Any inaccuracy existing in the pantograph, due to distortion in the arms or flexibility in the angles, will cause an error in the results.

Formula for Using a Pantograph.—The formula for using a pantograph may be reduced to a simple proportion as follows: The limit of the pantograph is to the setting of the pantograph as a larger scale is to the smaller scale. For example: If an 84-cm. pantograph is used and it is desired to pantograph a map of a scale of 1 : 10,000 to a scale of 1 : 20,000.

$$84 : X \quad :: \quad \frac{1}{10{,}000} : \frac{1}{20{,}000} \quad \text{or} \quad \frac{84}{X} = \frac{\frac{1}{10{,}000}}{\frac{1}{20{,}000}}$$

Solving the formula for X,

$$X = 42,$$

which is the setting for all movable parts on the pantograph. This problem both demonstrates and proves our formula, since the scale of 1 : 20,000 is just half of 1 : 10,000; and as the pantograph is an 84-cm. instrument 42 cm. is just half the capacity of the instrument. If it is

desired to change a scale of 1 : 8,000 to 1 : 14,000, or vice versa, using the same pantograph,

$$84 : X \;::\; \frac{1}{8{,}000} : \frac{1}{14{,}000} \quad \text{or} \quad \frac{84}{X} = \frac{\frac{1}{8{,}000}}{\frac{1}{14{,}000}}$$

and 48 is obtained for the setting on our movable parts. Should it be desired to change 1 : 8,000 to 1 : 14,000, the data are placed under the long arm of the pantograph and copied under the short arm. If it is desired to change 1 : 14,000 to 1 : 8,000, the data are placed under the short arm and copied under the long arm.

CHAPTER XIX

METHODS OF ASSEMBLY

The Paper Traverse Method.—This method can be used to obtain secondary control from the photographs themselves. It is applicable when constructing either a mosaic or a photographic map. If the photographs are corrected for tilt by rectifying and brought to a uniform scale a photographic map of considerable accuracy can be constructed by this method.

The operations of the paper traverse method are as follows:

1. Assemble a rough mosaic with contact points by matching images in the zone of overlap. This first assembly is for selecting points on the photographs to be controlled, checking the photographs, and as a reference when making the final mosaic or photographic map.

2. Select about nine points for each 15-minute quadrangle well distributed over the area on the photographs to be used as primary control. These points should be easily identified on the ground and should be suitable for easy field control.

3. The photographs containing the selected points for primary control are then turned over to the field party. They then proceed to control these points by ground methods.

If there is considerable relief the approximate elevations of control points should be taken. These elevations of control points will help check various discrepancies and give a basis for approximate contour intervals as estimated with a stereoscope.

4. Select and mark two points on the first photograph of a strip. These points must also appear on the adjacent photographs of the same strip. The first point must be the center or near the center of the first photograph and also must appear near the edge of the second photograph. The second selected point will be near the edge of the first photograph and be represented on the second photograph at or near the center.

5. The remaining photographs of this strip and all other strips

are marked in a like manner. Three points must be selected on each photograph except the first and last of each strip.

6. Place a sheet of tracing paper (vellum) on a drafting table.

7. Place the first photograph of the first strip on top of the tracing paper in the same position as the like photograph in the rough mosaic. A small hole is punched (with a small needle) through the photograph and tracing paper at each selected point. The positions of the selected points on the first photograph now appear on the tracing paper. These points on the tracing paper should be marked with numbers corresponding to the numbers on the photograph. If a control point appears on the first photograph it should also be punched through to the tracing paper and numbered thereon.

8. Remove the first photograph and place the second photograph of the strip over the punch marks on the tracing paper. This is accomplished by pushing needles through the like points on the second photograph and locating therewith the corresponding holes on the tracing paper.

9. The third point on the second photograph is then punched through to the tracing paper and numbered on the tracing paper to correspond with the number of that point on the second photograph. This operation is continued until the strip is completed.

When a control point appears on a photograph it is also punched through to the tracing paper and numbered. This operation results in a succession of marks on the tracing paper, each mark representing a point near the center of the photographs or a control point. The tracing paper is then referred to as a paper traverse.

10. Similar paper traverses are made on the tracing paper from the photographs adjoining laterally. These lateral paper traverses are made, where required, as a tie between parallel strips.

11. In order to obtain the tentative scale of the mosaic, measurements are made on the tracing paper of distances between several control points. The results of these measurements are compared with actual distances between the same control points as shown by field notes on sheets.

12. Plot on the mount a polyconic projection at this scale.

13. All of the control points are accurately plotted at this scale from the field notes. From this study the final scale for the mosaic is determined.

14. A proportion is worked out between the final scale and the tentative scale. The control is then replotted to this final scale. This can be accomplished by either drawing rays from the bottom point on the central meridian (origin) of the projection to all control points, measuring the distances from the origin to these points and then increasing or decreasing their distances in accordance with the proportions between the tentative and final scales, or by replotting the control points to a corrected projection. If the latter method is used, the first projection should be plotted on drawing paper rather than on the mount.

15. Compare the paper traverses with the control as finally plotted. The traverses which are long or short and are close enough to justify their adjustment are adjusted and balanced, the same methods being employed as in a ground survey.

16. The adjusted traverses and control points are then laid on the mount in their proper positions and punched through to the mount and numbered thereon to correspond with the numbers on the tracing paper. The mount is then prepared for the assembly of the prints.

17. The prints after being cut (only the centers being used) are then laid and pasted on the mount in the positions as indicated by the plotted traverses and control points.

The photographs are oriented over their true positions by the means of needles projected through the points on the picture to like points on the mount.

A correction for elevation should be made on prints which contain control points. If the control point is higher than the datum plane, then the point on the photograph should be moved toward the center of the photograph. If the control point is lower than the datum plane, then the point should be moved from the center. This movement of points on the photographs should be on a line drawn from the center of the picture through the control point to be moved. The distance that the point is moved will depend on the elevation and distance of that point from the center of the photograph. Rubber cement should be used to paste the prints on the mount.

Straight-Line Method.—For aerial photographic maps the straight-line method can be used for assembling single-lens, vertical area photographs, or for assembling and collecting data for the construction of line maps. This method is especially

suited for laying down an uncontrolled mosaic, as a much more rigid backbone is secured from which to adjust the remaining prints than would be the case if working from a single photograph. The steps of the method are as follows:

1. Locate approximately the principal point of each photograph by drawing its two diagonals.

2. Put the photographs on a table in regular order and, by matching the images of the overlap, fit them together in strips as accurately as possible.

3. Place a straight-edge on the assembled photograph strip so that its edge will pass as close as possible to the principal point on each photograph. It will be noted that a well-selected line should have an equal number of principal points at equal distances on either side of the line.

4. Transfer the line indicated by the straight-edge to the last photograph on the upper end of the strip. This is accomplished by drawing a fine line along the edge of the straight-edge. This line is drawn on only the last photograph.

5. Remove the photographs from the drafting table in order to extend the line, drawn on the first photograph, on each photograph in turn.

6. Select two sharply and well-identified points that are as far apart as possible on the straight line drawn on the first photograph and in the region overlapped by the second photograph.

7. Draw a fine sharp line on the second photograph, producing it to each side of the photograph through the two points that were recovered from the first photograph.

8. Repeat this process using photographs 2 and 3, continuing this until the line has been carried on all photographs in the strip. There will be then on each photograph a line in the same azimuth with all other lines on the other photographs.

9. Draw a straight line longer than the strip of photographs on a large piece of paper, or, when a mosaic is being constructed, draw this line on the mounting.

10. Place the first photograph over this line which was drawn on the paper or mounting and so orient it that the line on the photograph will superimpose the line on the paper or mounting.

11. The first photograph is held in position in any convenient manner and the second photograph adjusted over the straight line and slipped along with the same orientation until any point on or

near this line is exactly over the same point of the first photograph. These photographs are then joined as accurately as possible by this method and should be firmly fastened together in this position. This procedure is continued until the entire strip has been laid down.

If the line of flight has been irregular it will be impossible to select a line throughout the entire flight that will not depart a considerable distance from the line of principal points. When this is the case, a line should be selected that will fulfill the desired condition for the greatest number of photographs. It will then be necessary to select another line for the remainder of the strip. When selecting the second line, the photographs should be laid out and joined as in the first case. The new line is then produced over the remaining photographs. The assembling is carried out in the same manner described for the single straight line except that two straight lines are used. The second line will make an angle with the first line, the size of this angle being determined by the lay of the photographs. The angle that these lines make with one another is obtained from that photograph on which the bend occurs. It is necessary to begin compiling the photographs at the bend and work both ways from that point.

The next step is to connect these strips. It will be noted that many cases will occur where no known control points are available for fixing the strip in its proper place. In such cases, those photographic flights, on which two or more control points occur, should be adjusted first. The strips without control will be dependent on these adjusted strips for their position. If there are any straight lines on the photograph, such as roads, railroads, section or fence lines, passing from one strip to the other, they will help fix the scale and the orientation of all detail in their vicinity. The intervening strips are then completed by the straight-line method, definite points that exist on both the controlled and uncontrolled strips being used as a basis for scale determination for the new strip. A single strip can be added on the side of the fixed strip in this manner and these in turn will serve to fix other strips.

Notes on the Straight-Line Method.—The straight-line method can best be used with the single-lens vertical photograph having a large overlap and very little distortion due to tilt and relief.

The straight-line method should not be used if at least 60 per cent successive overlap has not been secured throughout the flight.

The amount of relief and the perfection of the flying will determine whether it is best to use a single straight line for orientation or whether it is best to break the flight up into several sections. When the photographing is done over country of small relief it is generally possible to utilize a single straight line for orientation.

When using this method it is best to consider the photograph as extending from one known control point to another control point as parts of a traverse line.

A METHOD FOR ASSEMBLING A MOSAIC [1]

One method makes use of the fact that the separate strips will have been taken in approximately straight lines.

When speed is the main factor rather than accuracy, this method should prove useful when laying down an uncontrolled, or partially controlled, mosaic. It is not believed that this method would prove successful in constructing a photographic map. It is stated by Professor Jones that "it is possible to construct well flown mosaics about ten miles square which will fit a true map with the average of about 3/100 mile and seldom exceed 6/100 mile, and that the local discrepancies in mosaics which occur at the edge of the photographs need not exceed 1/100 mile, so that in circumstances in which control points can be provided at the rate of one per photograph, or about one per square mile, the absolute error should rarely exceed 1/100 mile. These results can be obtained in country in which local differences of elevation do not exceed some 5 per cent of the height of the airplane. Useful, though not as accurate, results might be obtained in somewhat more hilly country."

The following is the order of procedure:

1. Starting with the first photograph of a strip, lay out the entire strip by matching details in the overlap.
2. Fasten one edge of this strip with push pins.
3. Place under the strip two elastic bands about 1 or 2 in. from each side of the print and of sufficient length to extend about 6 in. past each end of the photographic strip.
4. Fasten these elastic bands to each print by means of a small daub of adhesive, as seccotine. Then weight the prints down until the adhesive has set.

[1] Devised by B. M. Jones. For a complete discussion, see his work: *Rapid Survey Methods*, Cambridge Press, London, 1920.

5. The strip is then released from the table, being now a chain of prints connected by two elastic bands.

6. After all strips composing the mosaic have been connected in this manner, they are then placed on the mounting (which in turn is placed on a large table) in the order in which they will appear in the finished mosaic and the ends of the elastic bands are fastened in place.

7. Next select a strip, as near the center of the mosaic as possible, that has been flown straight. Stretch this strip until the overlap portions of the prints match in detail.

8. Working from this central strip, adjust each strip in a similar manner on both sides until all the strips composing the mosaic have been treated in like manner. This general adjustment should be completed before attempting to make a detailed adjustment.

9. A detailed adjustment from print to print is now carried out. The detailed adjustment will necessitate a slight general readjustment. As each print is adjusted it is held in place by a lead weight. This weight should not cover too much of the surface of the print. Upon completion of the detailed adjustment the mosaic will have reached the most accurate assembly possible by this method without controls.

10. Starting with the corner print which is not overlapped with any other print, mark on the mounting the position of the edges that do not overlie any other print (it will assist in the final laying if two pin holes are made in the portion of the overlap of the first and second print). The first print is then disconnected from the elastic band.

11. Mark the print just removed with an identification number to correspond with the number written on the mounting in the space from which the print has just been removed.

12. Proceed in this manner until the entire board is cleared of prints. Then the elastic bands are removed from the board.

13. The prints are then trimmed, care being exercised not to trim away those edges which were used to fix the location of the prints on the mounting.

14. The prints are then pasted on the mounting in the reverse order, that is, in the opposite order from that in which they were taken up. It will be noted that no further adjustment should be made at this time.

To assemble a mosaic to control points when using this method,

a templet must be constructed on the scale of the mosaic. This templet can be constructed by making a light wooden frame containing squares of celluloid upon which the positions of the control points are marked. The templet is placed on the mosaic and moved about until the control points are near the points which they represent on the photographs. When the mosaic is compiled to control points it is better to fasten the rubber bands to two wooden laths clamped on the edge of the table instead of fastening the ends of the bands directly to the table. These laths are supported, just clear of the table, by thin packing pieces so that the elastic bands can be passed beneath them, turned over, and pinned. The laths can be unclamped and moved so as to carry the ends of all the elastic bands with them. In this manner the whole mosaic can be subjected to systematic linear strains at any stage of the completion. The mosaic strips are set up between the laths and given the first general adjustment, which will determine the shape of the mosaic.

By a systematic stretching of the mosaic the control points can be made to coincide with the corresponding points on the mosaic. The prints containing control points should be fastened in place, since the adjustment is made in order to insure that they do not move if further readjustment of the remainder of the mosaic is made.

A METHOD OF ALIGNING VERTICAL PHOTOGRAPHS

In the zone of overlap, select a pair of points which lie close to the course line between centers of consecutive photographs. Mark and label the two points on each of the two photographs to which they are common. Every photograph will then have two such pairs of points, one pair for each zone of overlap. Also label and mark all primary control points embraced by the photographs. The marked points of a series of photographs which span the area between two primary control points are then traced on transparent celluloid which is oriented over each photograph in turn according to the position of a pair of points taken from the photograph which has just been traced.

When tracing, it will appear that distances between some of the pairs of points are not the same for two photographs. Such discrepancies can be partially adjusted by changing on the tracing

the position of the outer point so that it will fall at a mean between the two places indicated. To accomplish this, the tracing is placed over succeeding photographs with the innermost point resting on its corresponding position, the tracing being carefully aligned with respect to the outer point. Then dot the mean position of the outer point. The first position should be erased from the tracing and the tracing shifted, being careful not to change its orientation until the new dot covers the corresponding point on the photograph. With the tracing in this position, the pair of points lying on the opposite side of the center of the photograph are traced. It will be noted that orientations must be made with all possible care. This will necessitate the dots being small and accurately placed both on the photographs and on the tracings. In this manner the tracing is carried from one primary control point to another, the two primary control points being traced.

This procedure is the method in which orientations can be made as accurately as the limited overlap allows. In comparison with the usual inaccurate method of joining overlapping photographs by matching points along their zones of overlap, this method will be found to give far more reliable results.

CHAPTER XX

METHODS OF ASSEMBLING LINE MAPS—RESTITUTION

Radial Line Method.—The radial line method is a system of paper triangulation derived from the photographs themselves, establishing the correct geographical position of the center of each photograph and also a number of control points by which the photographs can be oriented. As the work of tracing the detail from the photograph progresses, the control points referred to are used in eliminating to a great extent the inherent errors of the aerial photographs.

The method is based on the fact that lines drawn from the center of a vertical aerial photograph will indicate with sufficient accuracy the direction of those points through which the lines pass. The method can be compared with plane table intersection work, practically the same considerations being necessary.

The method of procedure is as follows:

1. When the controls are to be established by triangulation, distribute eight points, equally spaced, along each border across which the flights were made. (If the control is to be established by traverses, a point should be located every mile along the lines.) One point should be located near each corner of the three five-minute quadrangles forming the middle tier, making a total of 24 points for an area of about 240 square miles. In practice this arrangement is not always possible as the points may not fall as indicated, but in general they should conform to the arrangement as given. If possible the control points should be established after the photographs have been taken, in order to distribute them to accommodate the photographs.

2. Select and mark at least nine points on each photograph. These points should be so arranged that one point will fall near the center and the other eight distributed close to the borders of the photograph. The selected points will then be in groups of three, approximately aligned across the photograph, each group being

common to three photographs of a series (the photographs having a 60 per cent and 50 per cent overlap). The points near the center of the photograph should be as close as possible to the lines connecting the centers. It is best that the center of the photograph itself should be used, but it is necessary that all points be identified on all three photographs. Center points cannot be easily used unless they fall on or very near to some distinguishable object. The outer points should be near the outer borders of the photographs. These points must be well defined and easily identified on all photographs containing them.

3. If the photograph is not marked with notches to indicate the center, fragments of diagonals should be drawn on the photograph to give the center point. Each center point, after selection, is encircled and labeled with the number of the photograph which includes it, as *C*–1, *C*–2, *C*–3. Compound numbers, such as 1–1, 1–2 and 1–3, which are applied in systematic order, are best employed in labeling all points other than the center point, as compound numbers will indicate the relative positions of the points on the photograph. When intersection work is being carried out, all points should be marked with small dots surrounded by circles several millimeters in diameter.

4. Next draw a short radial line from the center of the photograph toward each label point, starting it near the point and stopping it about half-way to the center point. There are cases where a single point lying close enough to the center lines of all three photographs will not be available. This being the case, two points must be selected, one on each side of the center point. The additional points should be chosen to lie as closely as possible along the line connecting the centers of the adjoining photographs and the additional points labeled *A* and *B*.

5. Thus far only photographs of a single series have been considered. Points which are common to photographs of the adjoining series must be selected and labeled with the numbers of one photograph of each series by which the points are embraced. To be able to identify these points easily, they should be lettered with T, as 1 T 24.—No. "1" representing the number of a photograph in the series which includes the tie-point and "24" representing the number of a photograph in the adjoining series which also includes the same point. It is less confusing to do this after marking points in groups according to single series of photographs rather than to

attempt to select and mark all points of several series together. It will be sufficient to have tie-points on each side of every third and fourth photograph of the series. The points must be chosen so that they are common to at least two photographs of each overlapping series.

Primary control points should also be marked on each photograph containing them. This is usually done by including each such point in a small triangle about the size of the circles marking the other points.

6. A series of photographs marked as explained and spanning the distances between two primary control points are now laid out, overlapping each other so that a proper start and orientation may be made. When the photographs have been laid out, a sheet of transparent celluloid is placed over them and marked so as to give the position on the celluloid of the starting primary control point and the orientation that the celluloid sheet is to have with respect to the first photograph. The celluloid is then placed over the first photograph in three points: namely, the center of the photograph, a point near the center, and a point on the first photograph that will fall near the center of the second photograph. These points are traced and lines are drawn on the tracing from the center point to pass over each of the other labeled points. The first photograph is then replaced by the second, which is oriented under the celluloid by two points near the center of the photographs already traced. After the orientation has been made as carefully as possible, the position of the center of the second photograph and the position of the point which lies near the center of the third photograph are marked. Radial lines from the center of the second photograph are then drawn so as to pass over all other labeled points, thus forming intersections which give the position of two points that are common to the first and second photographs. These points are labeled on the celluloid. The third photograph is then inserted and the celluloid then shifted over it until the two-course line points coincide. In some cases the distance traced from one photograph will not be the same as the distance shown on the next photograph, this condition indicating either tilt in the photograph or considerable relief between the two points. When such a condition exists place the celluloid strip by the point near the center of the underlying photograph, orienting it with relation to the other point near the course line according to the direction. Note

whether the position of the two outer points, located by intersection, fall on their respective lines on the photograph. If they fall approximately an equal amount inside or outside their respective radial lines, shift the celluloid along the center line until each point falls on its proper radial line. If, as is sometimes the case, one outer point falls outside its radial line as the other point falls inside its radial line, this will indicate that the preceding photographs have been poorly oriented. When an outer point falls exactly on its radial line, the center of triangle of error is taken as its location. After treating a tilted photograph, or one affected by relief, note whether the scale of the tracing has been changed materially from the scale of the succeeding photographs. If the scale of the tracing appears the same as that of the succeeding photographs, the work of intersection has been successful. If the scale is found to differ materially from that of the photographs, the preceding work should be checked. This process is continued until all locations have been made of all labeled points of the series of photographs, including the two primary control points.

7. After obtaining the celluloid sheets of control points, preparation is made to reduce and adjust the points to the map projection. The reductions are usually made by pantograph to sheets of paper. The settings of the pantograph are obtained by the ratios of the distances between the primary control points concerned, as plotted, and those points obtained on the celluloid. Positions of the secondary control points are then transferred to the map sheet from the reduced tracing. Before accepting the results of any one reduced tracing, it should be checked with an adjoining reduced tracing, the two tracings having at least one point in common located by intersection, on every third or fourth photograph, by which comparison may be made. All points thus located on the map should be labeled to agree with their labels on the photographs.

General Data on the Radial Line Method.—Triangulation with the radial line method can be expanded over distances three or four times the width of the photograph used.

Photographs used in this method should have at least 60 per cent consecutive and 50 per cent side overlap.

High relief will distort the trueness of radial lines. When mapping on large scales the limit of relief is lower than when mapping on small scales. The amount of relief between successive photographs should not exceed 900 ft.

Single-lens vertical photographs should have a circuit of primary control points equally distributed around the borders of the area and two intermediate lines of points across the area. The number of these points depends upon the size of the area mapped and the method of establishing the primary control.

Not more than 10 to 12 single-lens vertical photographs should span the distance between control points.

Points along the course line other than the central points need not be well located so long as by selection they fall close to the lines joining the centers of the photographs.

Locations cannot be made by intersection in a limited zone between the centers of the photographs. This is not important as this zone is little affected by tilt or relief.

Reasonably good plane maps can be made with aerial photographs which do not overlap as much as 50 per cent, but errors of tilt and relief are not as easily eliminated. Their use, therefore, should be confined to comparatively flat country. There should be at least 25 per cent overlap to afford satisfactory orientation. Additional primary control points must be used where the overlap is over 50 per cent. The number of these points varies with the relief of the country mapped.

PLOTTING FROM VERTICAL PHOTOGRAPHS

The pantograph is probably the best method by which to plot data on a line map from vertical photographs. It is more rapid than the photographic method and will permit readier adjustments of details when discrepancies appear in the data taken from the outer parts of overlapping photographs. If the map projection is divided into quarter sheets or smaller sections it may be used in multiples. The pantograph is set in proper relation to the map and the desired data transferred directly thereon. The scale of reduction for setting the pantograph is obtained by taking the ratio of distances between points of the photograph and corresponding points of the map. To give a mean ratio, two pairs of points should be used. These points should be so situated on the photograph that lines connecting them will pass through or near the center of the photograph. A ratio that has been so determined will tend to average the distortions on the photograph. The photograph, by means of the pantograph, should then be

From Hamilton Rice Expedition 1924-1925.

FIG. 56.—DIFFERENCE BETWEEN A MAP MADE FROM AERIAL OBLIQUE PHOTOGRAPHS (ABOVE) AND A MAP MADE BY GROUND METHODS (BELOW).

A section of the Rio Negro some distance above where it joins the Amazon River. The Rio Negro, here, is about 17 miles wide and filled with islands, as the upper map clearly shows. The ground method (lower map) showed the river to be over 30 miles wide and with comparatively few islands.

oriented with respect to the map, by a pair of such points and not by two points whose connecting line does not pass close to the center of the photograph. Data should be taken only as far from the center of a photograph as the mean distance of overlap. At the junctions slight adjustments will sometimes be required. The photograph should be divided into sections and data from one

From Hamilton Rice Expedition 1924-1925.

FIG. 57.—A MAP OF A PREVIOUSLY UNKNOWN REGION.

Map of the Amazon Basin made from a series of vertical photographs.

section transferred to the map before obtaining data from the other section. This system will avoid repetitions, omissions and confusion.

Some symbols cannot be formed with the pantograph. Details of the map should be gone over with pencil, as each section of the photograph is completed, in order to form symbols and to strengthen any dim lines. When speed is essential, two men can work to advantage with a single pantograph. While one is manip-

ulating the pantograph, the other will symbolize and strengthen any dim lines. Data obtained from photographs can be assembled on map projections by pasting together photographic reductions of single photographs, or of mosaics made up of two or more photographs which have been inked to retain the desired data and bleached to remove irrelevant data. This method is suitable only when the relief of the area is not high and when a large number of control points are available.

The Composite Vertical Photograph.—These photographs are generally used to assist in the construction of line maps. They have not proven satisfactory as a means of making either the mosaic map or the photographic map.

Plotting from Composite Vertical Photographs.—The wing pictures of the composite photograph are more distorted by tilt and relief than the center photograph. In plotting data from them this fact should be kept in mind. All possible care must be taken to orient the photograph accurately with respect to the map positions of the control points when the pantograph is being used. It is best to determine a scale on each side of a photograph. The pair of points used to determine the scale for a side should be the center and another control point lying near the limit at which the plotting work of the particular photograph will be stopped. It is recommended that data should not be plotted which are farther from the center than the mean lines of overlap. Any point which falls near the mean line of the overlap will therefore be used together with the center point to determine the respective side of a particular photograph so as to set the pantograph. If there has been sufficient longitudinal overlap, it is usually not necessary to take data outside of a middle zone a little more than half as wide as the photograph. When making joinings of data taken from two photographs, an examination should be made for discrepancies and where they occur adjustments can be made by shifting critical points toward, or away from, their proper centers in order to give mean positions. Details can be adjusted with sufficient accuracy by estimation. This is accomplished by lining the eye with the center of the photograph and the point to be shifted. When employing photographs of terrain of high relief, data along tops of ridges should be adjusted together and data in valleys together.

The Advantage in Overlapping more than 50 Per Cent between Parallel Strips.—

1. The orientation of every photograph could be made directly on the most accurately located points in the area.
2. Those parts of the area directly beneath the center of the photographs, where points cannot be located by intersection if the overlap is less, could then be located by intersection.
3. Errors due to occasional tilting in individual photographs could be more easily eliminated.

The securing of an increased overlap between a series of photographs will necessitate the taking of one additional series to cover a 15-minute quadrangle.

RESTITUTION

Methods of restitution are based on the principle that straight lines on the ground are pictured as straight lines on the photograph. A means of rectifying errors caused by tilt is thus afforded. Restitution will not eliminate errors arising from other sources. All present methods of restitution have their limitations.

One of the most satisfactory of the several graphical methods is known as the paper strip method (Four Point Method). This method requires at least four points of control. The best distribution of these points is achieved when they form a quadrilateral figure which embraces a large portion of the photograph. The four points are labeled on the photograph to agree with the labels on the map. Lines are then drawn on both the photograph and map from each of the points to the other points, and the lines are then prolonged to afford convenient lengths. A strip of paper having a straight edge and about two or three times longer than the photograph is then placed over the photograph so that the straight edge crosses the lines drawn from one of the points to the other point. It is then held in place with weights. The edge of the paper is then marked where these lines intersect. It is also marked where lines, drawn from the pivot point to any points to be located, cut it. A straight-edge is used to project these lines to the edge of the paper. The strip of paper is now placed on the map and shifted until the marks corresponding to the lines of the map fall

on their proper lines. When this position is found, the paper is weighted and lines are drawn from the pivot point toward marks representing the points to be located. Similar strips of paper are used to obtain directions to the positions sought from the two other control points. Intersections will be made in this manner, which will give the desired locations. Maximum accuracy is obtained by choosing as pivot points those three points of the four points which give interior direction lines to the points whose positions are desired.

Triangular Division Method.—This method is in principle a grid method, in which the photograph and the map are systematically divided into numerous small homologous triangles, the details thereafter being sketched in according to their relation to the triangles. For this method at least four points are required. If only four points are available, they must be so related as to form, both on the photograph and on the map, a trapezoid. If more than four points are available, to form a polygon the conditions are simplified because diagonals may be used to build the triangular net. The procedure for four points is to prolong the sides of the trapezoid to intersect and to draw the diagonals of the trapezoid, and then to connect each of the meeting points with the intersection of the diagonals and prolong the lines to intersect the sides of the trapezoid. Each point thus formed by intersection serves for drawing other lines to divide the photograph into triangular sections. This process is carried sufficiently far to afford a number of guiding triangles for sketching. It is best to completely subdivide a small part of the trapezoid first and sketch it before completely dividing the other part. The sketching will be made easier if inks of several colors are used to draw the lines on the photographs. It will usually be necessary to mount the photograph on a sheet of paper large enough to embrace the points where the sides of the trapezoid meet on being prolonged. While this method is the fastest, it is not so accurate as the paper-strip method.

Other Methods.—There are several other graphical methods, but most of them require elaborate constructions and are too tedious to be practical. Restitutions which are made photographically are in many respects the most satisfactory. By photography, a photograph can be rectified so that it can be used in connection with other overlapping rectified photographs to plot points with great accuracy. Four points are usually required in all photo-

graphic methods. For accurate work it is also necessary to know approximately the elevations of the control points. All methods of restitution are somewhat complicated and require considerable training. The principles of photographic restitution are employed in transforming the oblique photographs of the tri-lens camera to the plane of the center negative in order to make a composite vertical photograph.

OBLIQUE AERIAL SURVEYS (CANADA)

By A. M. Narraway

CHAPTER XXI

OBLIQUE AERIAL SURVEYS [1]

BY

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Oblique aerial surveying may be defined as the art of mapping and interpreting ground features from oblique or perspective aerial photographs.

This chapter is confined to an explanation of the methods employed in mapping from oblique photographs. At the same time, it should be kept in mind that there remains a larger field including the study of the individual photograph for detailed information respecting forest cover, geological formation, soils, water powers, and engineering and development problems which cannot be more than touched. Experience has shown that notwithstanding that the photographs permit the making of a complete and reasonably accurate base map yet the interpretation of the photograph is really the larger part of aerial surveys provided the interpretation is done by an expert.

The oblique photograph is not as readily reducible to map form as the vertical, but it covers a far larger area, with consequent lower flying costs per square mile of photographed country. In unexplored country it has a particular advantage over the vertical photograph in that the area covered by the oblique is so large that irregularities in the flying do not result in gaps and frequent reflights.

[1] This chapter is descriptive of oblique aerial mapping which has been developed by the Topographical Branch of the Surveys Bureau, Department of the Interior, Canada, in connection with the mapping and investigation of considerably over 125,000 square miles of mostly unsurveyed and largely unexplored country.

In Canada the oblique photograph is being used to map the extensive areas of forest and lake country lying largely within the Laurentian shield. Here as a rule there is no very great difference in the elevations of the lakes and rivers; in fact, the country is generally one of rather low relief. The most striking feature of this type of country is the maze of waterways, lakes and rivers, so intricate and so involved as, practically speaking, to preclude the mapping by ground methods of anything except the main routes and waterways.

Prior to the advent of aerial photography, the methods employed most generally in the mapping of this type of country were micrometer or stadia traverses. These were carried on along the main waterways—the methods of transport being canoes in the summer and dog trains in the winter. The resulting maps were of necessity restricted to the actual waterways traversed but were augmented by sketches from information supplied by Indians, fur traders and explorers. A stadia party traversing on an average 7 or 8 miles a day during a season, four months being the average length of a season's work in the north, could cover only about 800 miles of traverse. The resulting map was of necessity restricted to the actual visible shore line.

On the other hand an aircraft traveling at a ground speed of 70 miles an hour could in three hours photograph obliquely a strip 8 miles wide, or approximately 1680 square miles.

The resultant pictures, complete in detail and comprising not only water features but also the forest cover and the geological formation, form a library from which it is possible to study the country from many different angles.

Of course aerial photography does not do away with the ground surveys altogether; rather it is used in conjunction with them. The ground surveyor provides, at suitable intervals, accurate traverse or survey line control, which is the framework on which the aerial surveys are based. Since the photographs themselves supply all the detailed information, the surveyor can confine his attention to the careful determination of the position of a comparatively few control points, and, detail being eliminated, can make much more rapid progress. In mapping by means of aerial photographs it is preferable, except in the case of cut lines, to photograph first, then allow the surveyor to take the field with the pictures to assist him. By means of these he is enabled to pick

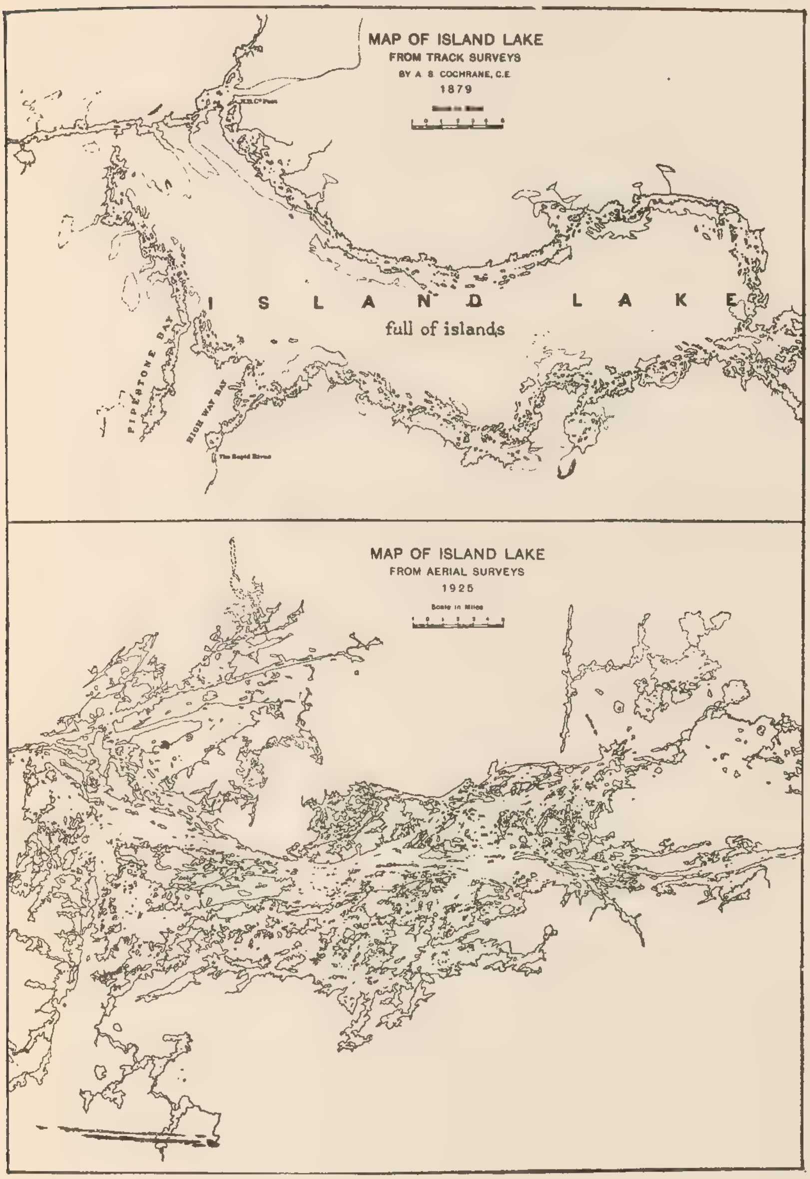


FIG. 58.—THE OLD AND THE NEW

Notwithstanding that Island Lake is over sixty miles in length lying one hundred miles away from main transportation routes, it was mapped completely by oblique aerial surveys in a few hours; and the photographs reveal the character of the terrain even many miles away from the lake itself.

out his route, make his plans for supplies and transport, select camp sites and desirable positions for monuments, and, in fact, plan in detail his whole survey in advance.

The Principles of Oblique Photography.—Before passing to the detailed procedure of oblique photography and mapping it is desirable to describe briefly the principles and assumptions upon which it is based. Oblique mapping photographs are so taken that the horizon line appears in the upper part of the photograph, preferably about seven-tenths of an inch from the margin. This horizon line defines the angle of the axis of the camera with the horizontal at which the photograph was taken, or as it is commonly called, the tilt. This angle of tilt together with the altitude of the camera above the ground and the focal length of the lens comprise the data from which the plot is made.

In plotting, the photograph is treated as a perspective, the surface of the earth as a plane, and the position of the camera as the origin of another plane parallel with the assumed plane of the earth's surface.

In order to transfer the topographical detail of the photograph to the map the photograph is covered with imaginary squares, distorted of course since the photograph is in perspective, which are of predetermined dimensions and correspond each to each with ruled squares on the plotting paper. The photograph, however, was taken from far above the ground and the resultant perspective is not in the ground plane but is in the camera plane, and the horizon line in which the parallels of the perspective merge is not the horizon line of the photographs but an imaginary horizon line in the plane of the camera.

In practice these squares are 10 chains to a side, and correspond to squares ruled on sheets of tracing paper on a scale, usually, of one mile to one inch.

It would of course be impracticable to rule with precision a series of squares in perspective on each photograph. Accordingly, transparent perspectives, or perspective grids—or more commonly, grids, are constructed to the size of the photograph for the focal length of each lens used on the survey. Such grids are made, in Canada, for each difference of one-tenth in the marginal distance of the horizon (which defines the tilt of the photograph), and for each 25 ft. of difference in altitude within the range of flying height occurring in the survey. These grids are drawn on

paper to four times their natural size, reduced photographically and reproduced on glass or celluloid. The glass is the more satis-

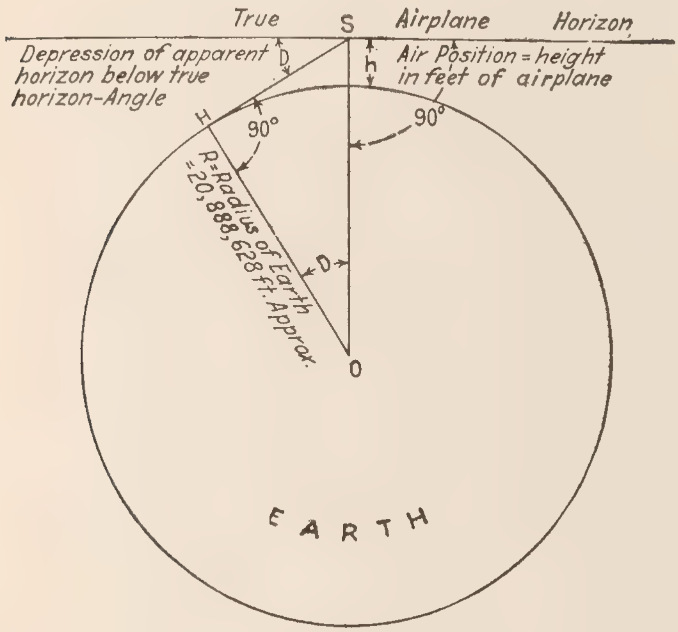


FIG. 59.—CONSTRUCTION OF PLOTTING GRID: DIP OF APPARENT HORIZON

$$\text{Tan Dip} = \tan D = \frac{SH}{OH} = \frac{\sqrt{SO^2 - OH^2}}{OH} = \sqrt{\frac{2\,h}{R} + \frac{h^2}{R^2}}.$$

As $\frac{h^2}{R^2}$ is very small, it may be neglected without appreciable error.

$$\text{Therefore } \tan D = \sqrt{\frac{2\,h}{R}} = \sqrt{\frac{h}{10444314}}.$$

Also, D being a small angle, we may write $\tan D = D \tan 1''$.

$$\text{Therefore } D = \frac{\tan D}{\tan 1''} = 206265 \sqrt{\frac{h}{10444314}} = 63.82\sqrt{h}.$$

To correct for refraction multiply value of D above by 0.9216.

Therefore Dip in seconds $= 58.82\sqrt{h}$.

Thus: For altitude of 5000 feet, Dip $= 58.82\sqrt{5000} = 4159'' = 1°\text{–}09'\text{–}19''$.

factory as it retains its dimensions. The celluloid grids being unbreakable are more suitable for field use.

Construction of the Grid.—In the construction of the grid three factors are required:

1. Height of camera above the ground.
2. Focal length of lens used.
3. Tilt or marginal horizon distance.

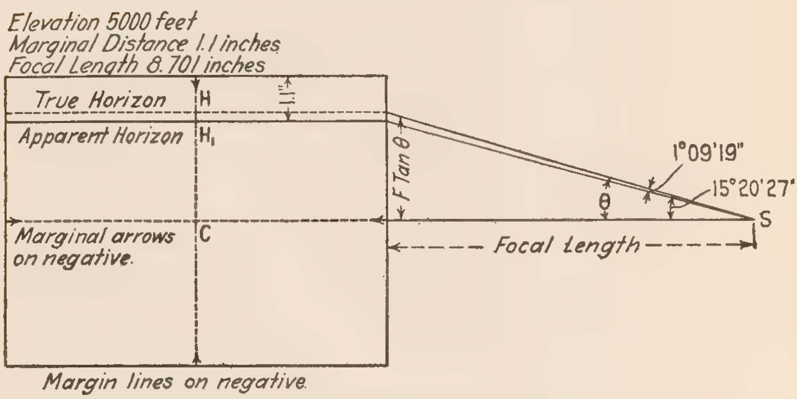


FIG. 60.—CONSTRUCTION OF PLOTTING GRID: DEPRESSION ANGLE

To determine depression of camera axis below apparent horizon (1) Mark plate center by joining marginal arrows appearing on each negative, referencing the position of principal point as at C; (2) CH_1 is $\perp$ to apparent horizon line and distance $CH_1 = 3.487 - 1.1 = 2.387$ in. Tangent of apparent depression angle $= \frac{CH_1}{\text{focal length}} = \frac{2.387}{8.701} = \tan^{-1} = 15° \ 20' \ 27''$.

To obtain true depression angle of camera axis add angle of dip of apparent horizon at 5000 ft. to depression angle of camera axis below apparent horizon. Thus, in this case, $15° \ 20' \ 27'' + 1° \ 09' \ 19'' = 16° \ 29' \ 46'' = \theta$.

Distance from plate center to true horizon line $= CH = F \tan \theta = 8.701 \tan 16° \ 29' \ 46'' = 2.577$ in.

The construction drawing for plotting the grid for elevation 5000 ft., marginal distance 1.1 in., focal length 8.701 in., is shown in Fig. 65 in which only the solid lines and descriptive notes in vertical letters appear on the finished drawing. The dotted lines and the remaining notes and letters are used to indicate the process of construction. This drawing is the actual size of the finished grid, but in practice the grid is drawn to a scale four times as large and then photographically reduced on a negative from which the positives are made by contact printing on glass or celluloid. In this explanation, however, it is assumed that all measurements are to actual size and explanatory drawings illustrate the process step by step. The dip of the apparent horizon from the airplane hori-

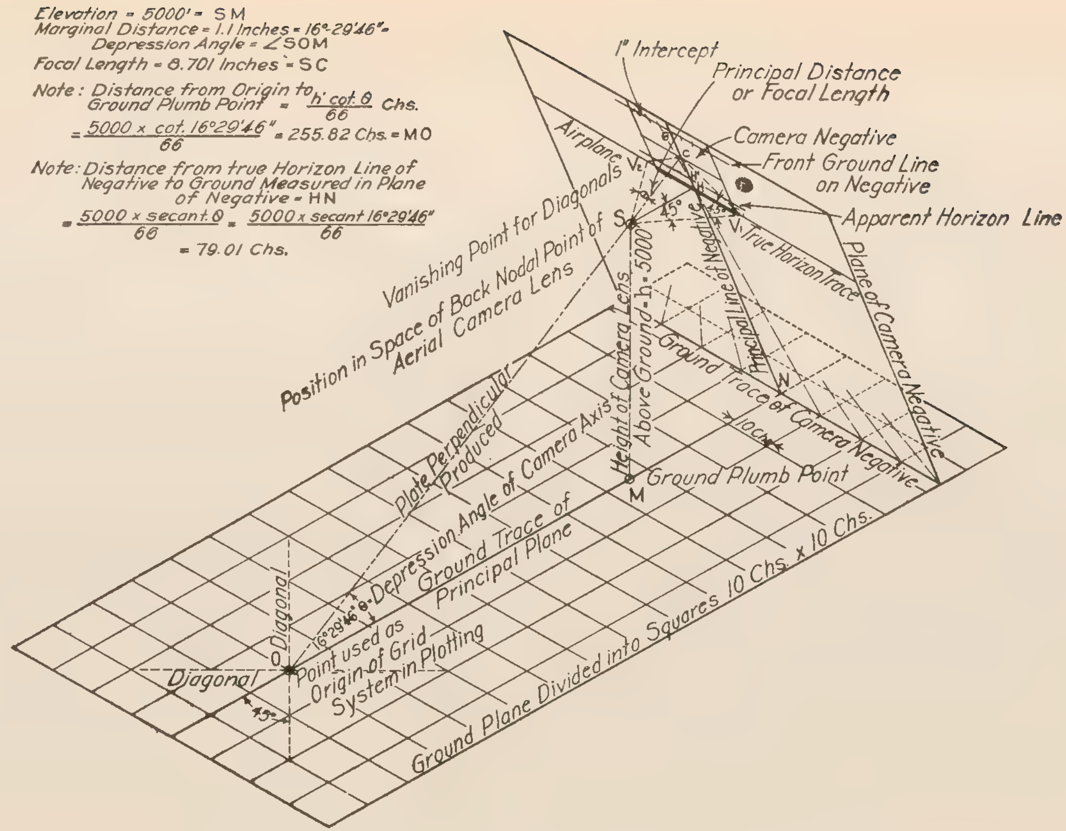


Fig. 61.—Construction of Plotting Grid: Determination of Squares

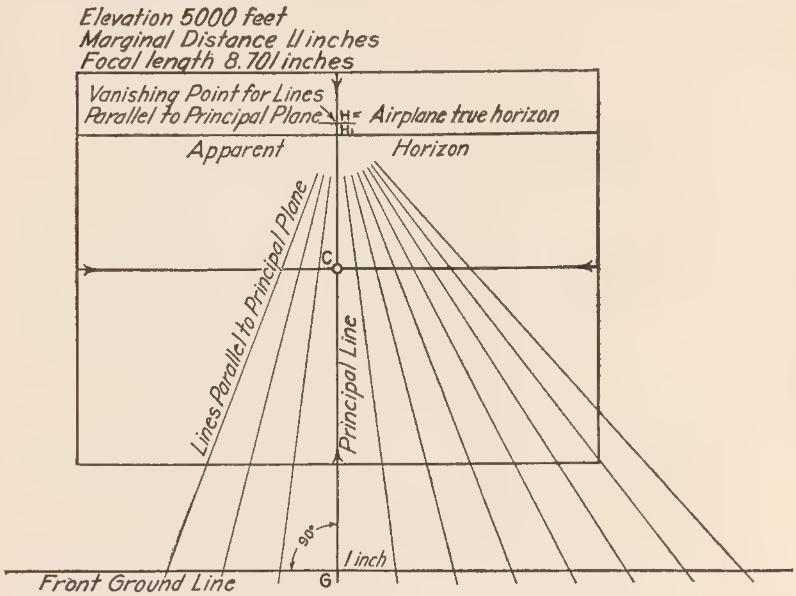


FIG. 62.—CONSTRUCTION OF PLOTTING GRID: VANISHING POINT FOR LINES PARALLEL TO PRINCIPAL PLANE

Distance from airplane true horizon to ground plane measured in plane of negative $= h$. Sec. true depression angle $= HN$, Fig. 61, $= \dfrac{5000 \text{ sec. } 16° \, 29' \, 46''}{66}$ chains.

Distance from true horizon line to front ground line at G where one inch measured on front ground line subtends 10 chains on ground trace of negative $= HG = \dfrac{5000 \text{ sec. } 16° \, 29' \, 46''}{66 \times 10} = 7.901$ in.

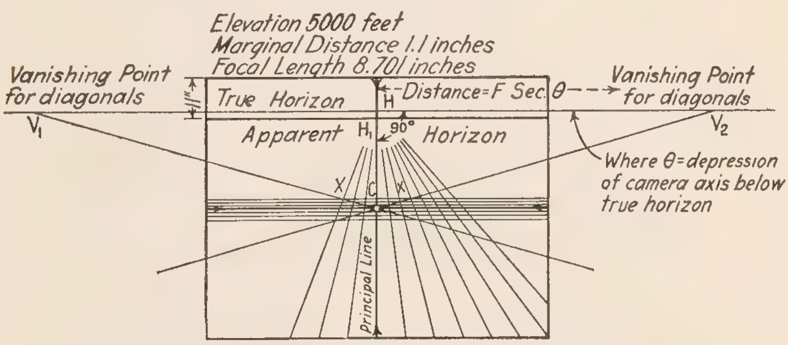


FIG. 63.—CONSTRUCTION OF PLOTTING GRID: VANISHING POINT FOR DIAGONALS

Measure on true horizon line distances HV_1, $HV_2 = F \sec \theta = 8.701 \sec 16° \, 29' \, 46''$ $= 9.074$ in. from principal line to vanishing points for diagonals. Join CV_1 and CV_2 and produce lines. Join corresponding pairs of intersections of converging lines with diagonal lines and thus extend grid as XX.

zon at the altitude of the air position, or 5000 ft., is taken from a table constructed by substituting in the formula,

$$\text{Dip in seconds} = 58.82\sqrt{\text{height in feet}},$$

the values of the altitudes through the range from which aerial

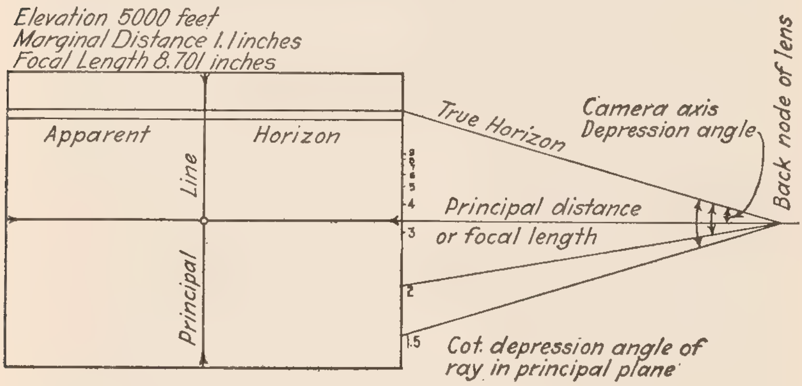


FIG. 64.—CONSTRUCTION OF PLOTTING GRID

Correcting factors marked on side as 1.5, 2.3, etc., refer to depression angles measured in principal plane from horizon trace whose cotangents are 1.5, 2.3, etc., and are used to correct distortions radial from ground plumb point for known elevated or depressed objects plotted.

photographs are taken. The derivation of the formula is explained in Fig. 59. For this particular case

$$\text{Apparent depression angle} = 1^\circ\ 09'\ 19'' \tag{1}$$

A table is also compiled to give the depression of the camera axis below the apparent horizon corresponding to the different marginal horizon distances, by substituting in the equation:

$$\text{depression angle} = \tan^{-1}\frac{3.487\text{ in.} - \text{marginal horizon distance}}{\text{focal length}}$$

the different values varying at intervals of 0.1 in. of the marginal horizon distance through the range presented by the oblique aerial photographs. In the case being considered, this amounts to

$$\tan^{-1}\frac{3.487\text{ in.} - 1.1\text{ in.}}{8.701\text{ in.}} = 15^\circ\ 20'\ 27'' \tag{2}$$

the perpendicular distance from the principal point to the upper marginal line of rectangle on the negative being 3.487 in.

To obtain the depression angle of the camera axis below the air position horizontal plane, add the two angles given by (1) and (2), thus:

$$1^\circ\ 09'\ 19'' + 15^\circ\ 20'\ 27'' = 16^\circ\ 29'\ 46''$$

$$= \text{true depression of camera axis.} \qquad (3)$$

The distance from the plate center along the principal line of the photograph to the true horizon $= CH = F \tan \theta = 8.701$ in. $\tan 16^\circ\ 29'\ 46'' = 2.577$ in. In the construction drawing, Fig. 65, a straight line parallel to the apparent horizon line or marginal line is drawn through H, as determined above. This is shown graphically in Fig. 60.

The size of square for gridding the photograph and the position of origin are now decided upon. The problem is clearly indicated in Fig. 61, where the ground plane is assumed to be divided into 10-chain squares, the origin of the system of divisions being at the point O where the camera plate perpendicular, produced, meets the ground plane, and two sides of each square are made parallel to the principal plane of the photograph. To construct the perspective of the squares shown in the ground plane in a simple manner is the next problem. By reference to Fig. 61 it is seen that lines parallel to the ground trace of the principal plane vanish in the plane of the negative at H, the point of the intersection of the principal line and true horizon line. The distance in chains from H to the ground measured in the plane of the negative along the principal line is therefore

$$\frac{5000}{66} \sec 16^\circ\ 29'\ 46'' \qquad (3)$$

In our construction drawing, Fig. 65, there is next marked off from H along the principal line a distance

$$HG \text{ equal to } \frac{5000 \sec 16^\circ\ 29'\ 46''}{66 \times 10} = 7.901 \text{ in.,}$$

and through the point G a front ground line perpendicular to the principal line is drawn and one-inch divisions are marked off along this line on both sides of the principal line. The points so marked are joined to the central vanishing point H. The lines so drawn represent one side of parallel sides of the projected ground plane squares. This is indicated graphically in Fig. 62, in conjunction

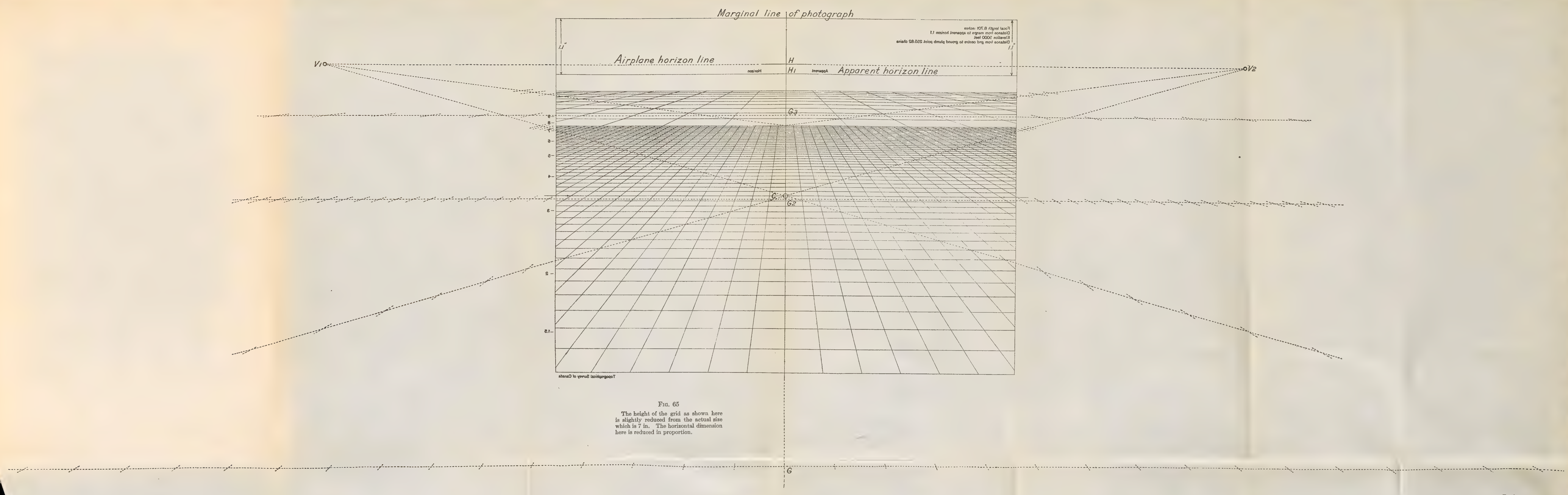


FIG. 65
The height of the grid as shown here is slightly reduced from the actual size which is 7 in. The horizontal dimension here is reduced in proportion.

To face page 310.

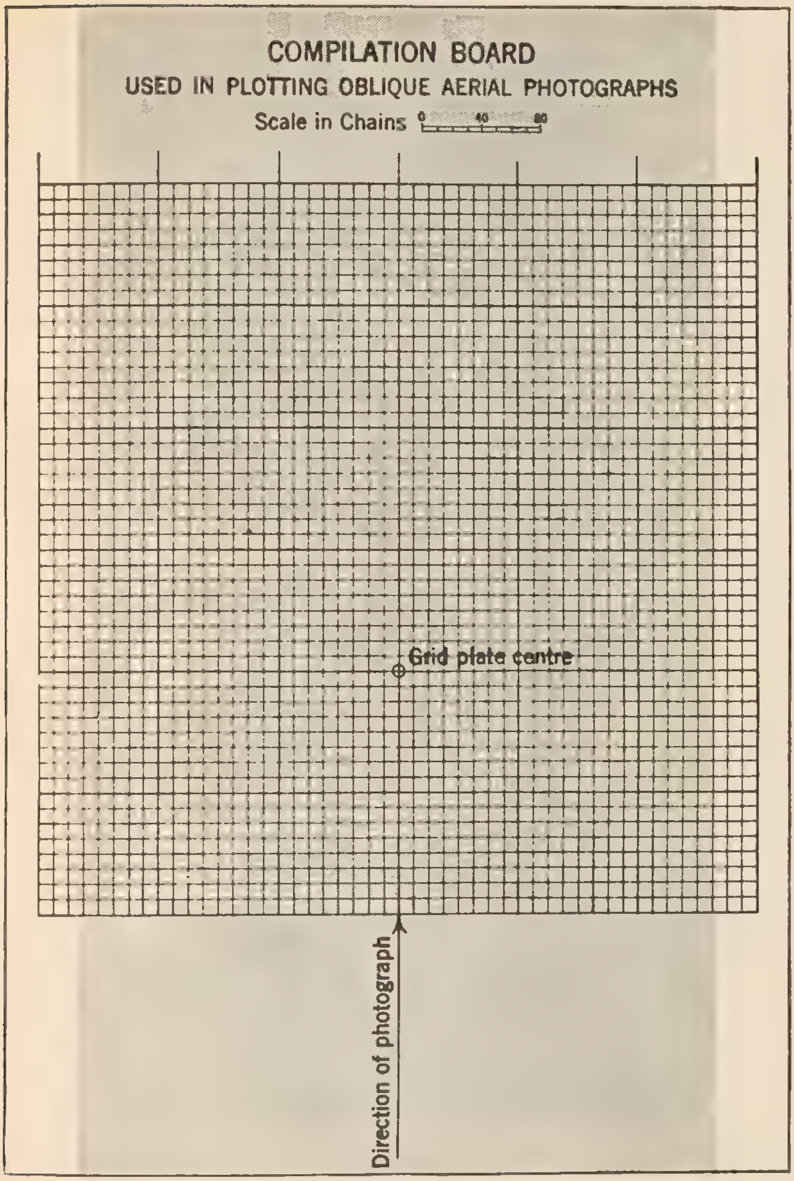


Fig. 66.—Compilation Board Used in Plotting Oblique Aerial Photographs

with Fig. 61, which shows that the triangles involved are similar. If necessary a second front ground line may be drawn at G_2, Fig. 65, distant $\frac{1}{3}$ of GH from H, and similar divisions of $\frac{1}{3}$ in. on this second front ground line may be joined to extend the gridding. A third front ground line is drawn through G_3, where $HG_3 = \frac{1}{8}$ of GH, and divisions of one inch on it mark the positions of parallel lines one mile apart on the ground plane.

The construction of the perspective of that set of projected parallel lines in the ground plane which are perpendicular to the principal plane of the photograph is greatly facilitated by making use of the diagonals of the squares. Referring to Fig. 61, the diagonals of the squares adjoining the point of origin O in the ground plane are drawn and when these diagonals are produced they intersect the pairs of parallel lines equally distant from the ground trace of the principal plane at points on the lines of which we wish to construct the perspective. Hence, referring to Fig. 61 the vanishing points for diagonals are found at V_1 and V_2, by drawing in the horizon plane of the air station represented by the back node of the camera lens at S, lines SV_1 and SV_2 making angles of 45 degrees with SH. Then

$$HV_1 = HS = SC \sec \theta = F \sec \theta.$$

Therefore on our construction drawing, Fig. 65, there are marked off on the true horizon line drawn through H, distances HV_1 and HV_2 each equal to

$$F \sec \theta = 8.701 \sec 16° \; 29' \; 46'' = 9.074 \text{ in.}$$

as measured from H.

The point of origin on the grid C, which corresponds to O in the ground plane, is joined to the vanishing points V_1 and V_2 and the lines are produced. The corresponding pairs of intersections of converging lines with diagonal lines are then joined, as is clearly indicated in Fig. 63. Diagonals for the mile squares are drawn to the vanishing points from the point on the principal line which marks the origin of the later squares, and corresponding pairs of intersections with equally distant converging lines are joined as indicated in Fig. 65.

The factors for correcting the plotting of features elevated to known distances above the level of the plane of the control points are merely the cotangents of the angles measured in the principal

plane which the visual rays make with the true horizon, and a method of locating them on our construction drawing is shown in Fig. 64.

The distance to the ground plumb point of each grid as meas-

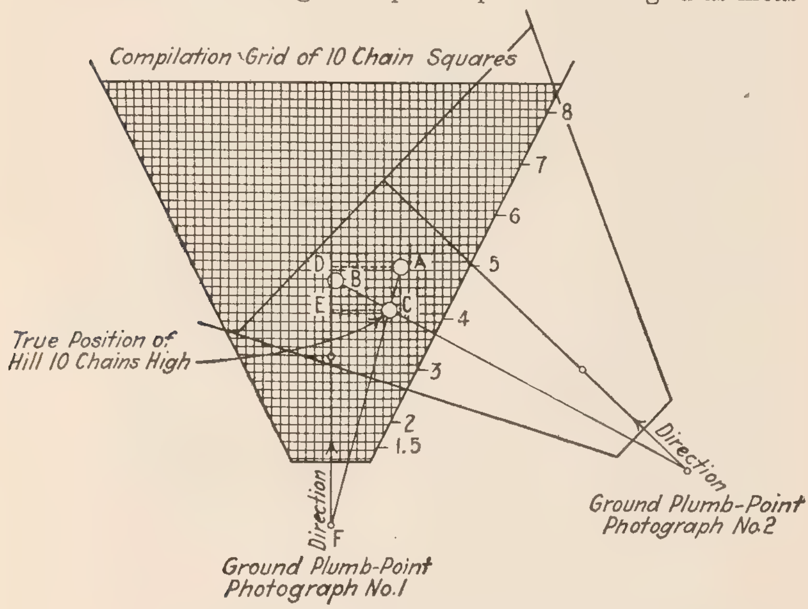


FIG. 67.—DISPLACEMENT CAUSED BY ELEVATIONS

A = Uncorrected position of hill 10 chains high (660 ft.) above ground as plotted from photograph No. 1. B = Uncorrected position of same hill plotted from photograph No. 2. C = True position of same hill determined from photographs No. 1 and No. 2 by joining uncorrected plotted positions to respective ground plumb-points. If height of hill (10 chains) is known, true position may be determined from one plot by projecting A on central line representing direction of photograph to D. Mark off towards F, DE = height of hill $\times$ correction factor opposite A on grid = 10 chains $\times$ 5 = 50 chains. At E draw EC perpendicular to DF meeting AF at C. C is correct position of hill.

ured on the plot from the grid origin is marked on each grid. Its

$$\text{distance in chains} = \frac{h \text{ (in feet) } \cot \theta}{66}$$

In this case $h = 5000$ ft. and $\theta = 16° \, 29' \, 46''$ and the distance

$$= \frac{5000 \cot 16° \, 29' \, 46''}{66} = 255.82 \text{ chains.}$$

This is illustrated in Fig. 61. If the construction drawing, Fig. 65, is transferred by photography to glass or celluloid, as is

done in the office of the Topographical Survey, it will be necessary to stamp the titles on transparent paper and mount them on the drawing in the manner indicated in Fig. 65, so that they will show properly on the finished grid, as on the latter all lines must be on that side of the glass which is in contact with the print when the grid is properly superimposed on it.

TAKING OBLIQUE AERIAL PHOTOGRAPHS

In order to gain a complete and comprehensive understanding of mapping from oblique aerial photographs it would be well to understand the methods employed by the photographer in obtaining these views. In actual practice the following methods are generally adhered to:

a. The photographic aircraft endeavors to attain and fly constantly at an elevation of about 5000 ft. for the duration of the flight. Due to unstable air conditions it has been found very difficult to maintain a constant elevation at this height, and, in order to register changes in elevation, a sensitive aneroid barometer is carried, which is read as each set of pictures is taken, and the reading is recorded.

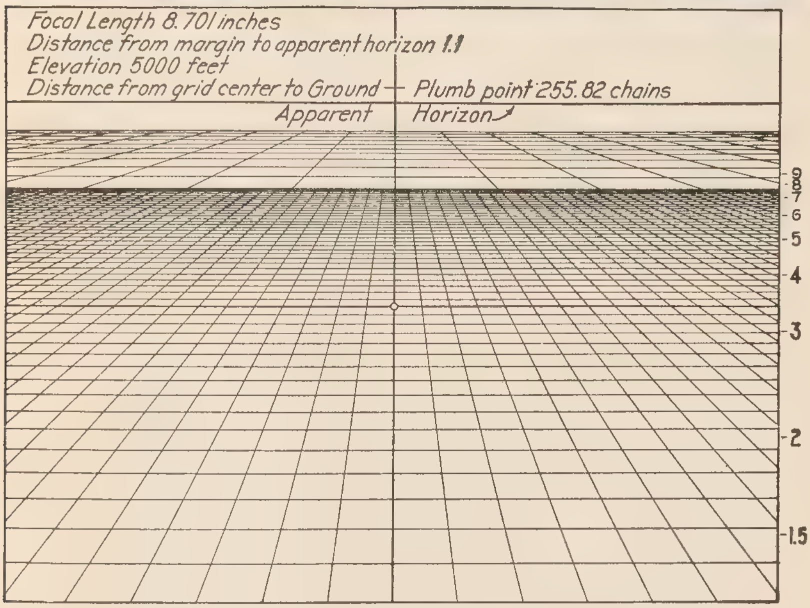
b. The usual method of taking these pictures is in sets of three exposures, one being taken in the direction of the flight and the other two to the right and left of the central one, at an angle of about 45 deg. with it. This gives an overlap between central and side pictures of about 25 per cent.

c. About $2\frac{1}{2}$ miles farther along the same line of flight another set is taken in the same manner, this procedure being continued until the flight is completed from some known ground control to another. The interval between sets is obtained by timing.

d. These flight lines are generally flown in an east and west direction in order to keep the camera lens out of direct conflict with the sun's rays, and thus avoid fogging on the prints.

e. At a distance of 6 miles from this flight line and parallel to it, another line is flown, this practice being continued until the whole area to be photographed is covered by a series of flight lines 6 miles apart.

Photograph to be Plotted. Approximate altitude 5000 ft.



Glass grid for 5000-ft. altitude, 1.1-in. marginal distance.

FIG. 68.—OBLIQUE PHOTOGRAPH AND CORRESPONDING GRID

f. Cross flights at right angles to the main flights are laid down at intervals of 30 or 40 miles and serve to strengthen the map in longitude. These are also controlled at their extremities.

g. A camera with a wide-angled lens is employed in order to cover the maximum extent of territory. In Canada a focal length of approximately 8 in. is generally used. This

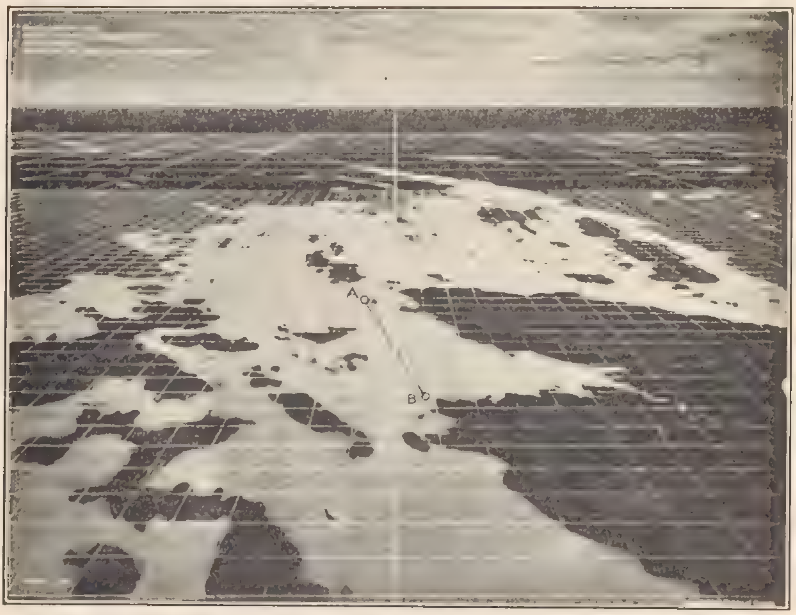


FIG. 69.—TRIAL 5000 FT. GLASS GRID SUPERIMPOSED ON PHOTOGRAPH

5000 ft. glass grid gives distance A–B = 92.1 chains. True distance A–B = 88.78 chains. Therefore correct grid altitude $= \frac{88.78}{92.1} \times 5000 = 4820$ ft.

is carefully determined to hundredths of an inch by laboratory methods.

h. The camera is so mounted that it is permitted to swing through an arc of 180 deg. in forward and lateral directions.

i. An oblique photograph to be serviceable must exhibit the horizon. The distance measured on the photograph between the horizon and the marginal line of the photograph defines the absolute angular depression at which the photograph was taken. This marginal distance which determines

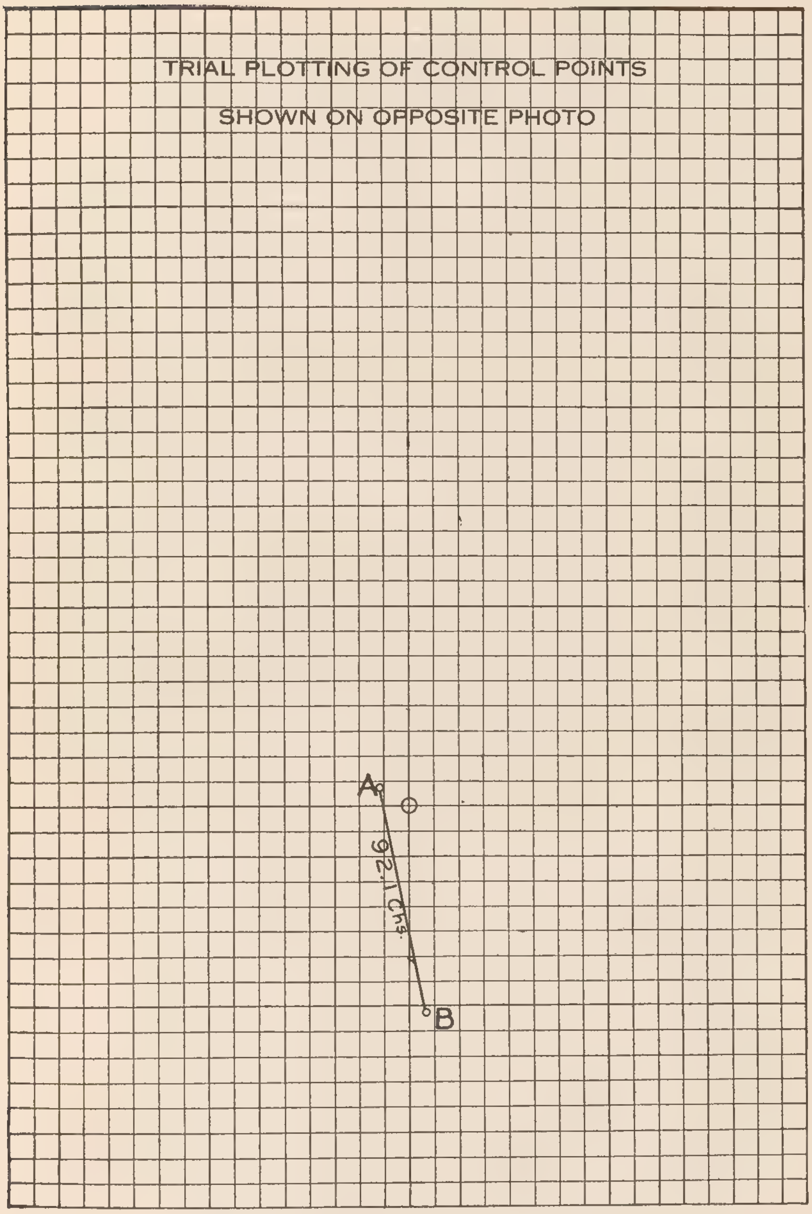


FIG. 69a.—GRID CORRESPONDING TO FIG. 69

the obliquity of the photograph is a governing factor in the selection of a required grid (referred to later) as it is obvious that the degree of obliquity of a photograph severely affects its perspective and therefore its scale.

FIG. 70.—CORRECT GLASS GRID SUPERIMPOSED ON PHOTOGRAPH
Elevation, 4825 ft. Marginal distance, 1.1 in.

The camera is tilted sufficiently to include the apparent horizon at a distance of 0.7 in. from the upper marginal edge of the photograph. The angle necessary to produce this tilt is determined and set on the camera sight, which can then be sighted upon the apparent horizon.

HOW TO USE A GRID

a. Join the photograph axes, and thus locate the principal point of the photograph. This is generally marked on the print by means of a small cross which has been etched on the camera plate.

b. Measure the marginal distance, that is, the distance from the apparent horizon to the marginal edge of the photograph

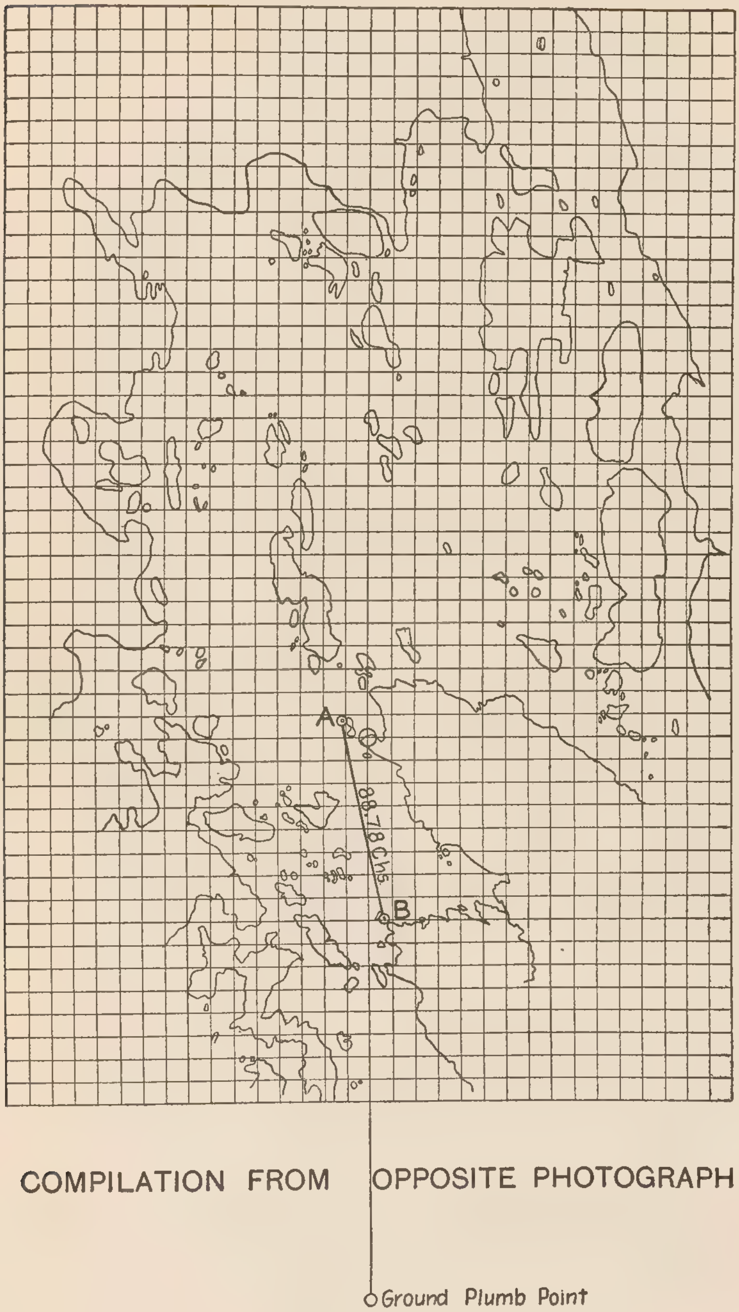

A
88.78 Chs
B
COMPILATION FROM OPPOSITE PHOTOGRAPH
Ground Plumb Point

FIG. 70*a*

along the line passing through the center of the picture and perpendicular to the apparent horizon.

c. Obtain the focal length of the lens used during the operation.

d. Determine the altitude at which the picture was taken.

e. Having selected a grid which will most nearly conform to the above requirements, superimpose it on the photograph so that the principal line of the grid passes through the

Fig. 71.—Oblique Aerial Mapping Photograph to Illustrate the Method of Taking Photographs

principal point of the photograph and the apparent horizon on the grid is tangent to the apparent horizon on the photograph at its center. Since the horizon line on the photograph is slightly curved and the corresponding apparent horizon line on the grid is a straight line, the grid line when correctly placed will appear slightly above the horizon at the edges of the photograph.

f. Transfer the information required from the photograph to the squared plotting paper, sketching the detail covered by

each square on the photograph on the corresponding square on the plot. The corresponding squares are identified by referring them to the center of the photograph, which is plainly marked on both grid and plot.

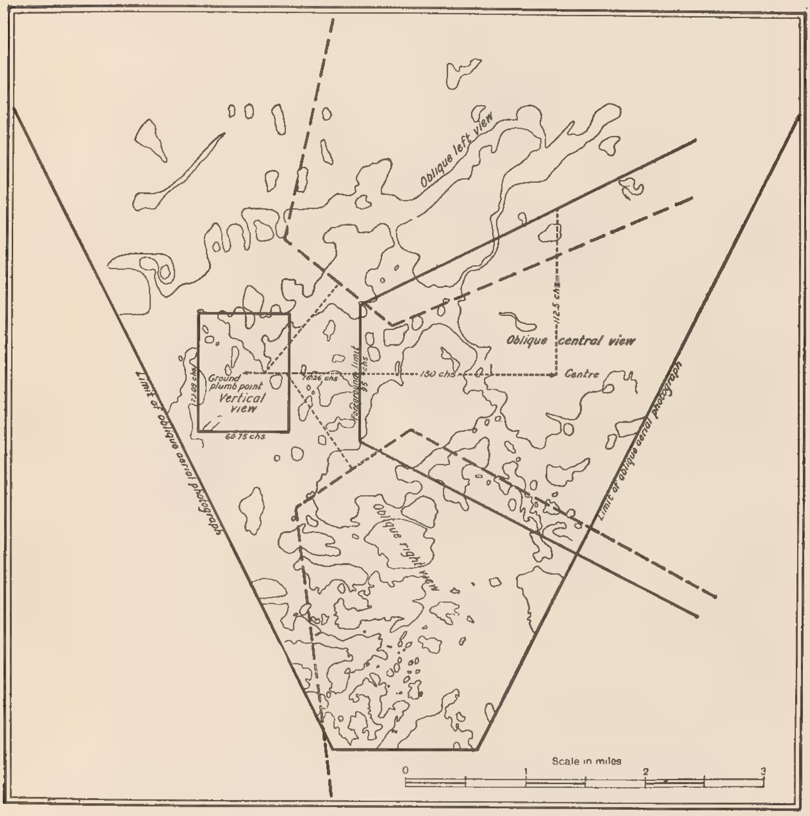


FIG. 71*a*.—PLOT OF OBLIQUE MAPPING PHOTOGRAPH SHOWING METHOD OF TAKING PHOTOGRAPHS

MAKING THE MAP

Compilation of the Map.—For the compilation of the map, we have the projection sheets on which the ground control has been drawn on the scale at which photographs are to be plotted. The remainder of the compilation is now dependent upon the interpretation and plotting of photographs arranged in parallel lines of flights from one control survey to another, and overlapping in every direction.

Azimuth Lines.—In order to correlate these lines of flight and properly orient the various sets of pictures taken, a simple method of alignment is adopted known as an "azimuth line." This is merely a straight line drawn on the prints and passing through the central pictures of the flight from one ground control to another governing the azimuth of the flight. In conjunction with this line a series of points are plotted to check the scale, or elevation at which the pictures are to be plotted.

To draw this line, it is best to lay out the necessary control pictures of the flight in order, and by inspection determine the inclination to drift or waver.

Then, beginning about the middle of the flight, draw a straight line through three or more well defined points in the foreground of the picture to an outstanding feature in the extreme background. These points are generally points of land in lakes, and are identified on the central pictures of the adjacent sets. In this way the line is produced throughout the flight from one ground control to another. These points should be chosen at water level, when at all possible, and carefully pinpricked.

If the azimuth line is coincident with the principal line of the photograph, it will always appear as a straight line on the ground in spite of changes in ground elevations; but when it departs from this line it may or may not be a straight line on the ground according to whether the ground is level or not. For this reason it is well to keep the azimuth line near the principal line of the photograph.

When, owing to drift in the flight or other change in direction, the azimuth line is found to depart appreciably from the principal line, another line parallel to it should be started to carry on through the succeeding photographs.

Parallel lines in perspective meet at a point on the true horizon—in this case the horizon of the plane of the photograph; and as the position of the true horizon is given on the plotting grid this can be transferred to the print, and the new line established by drawing it through the intersection of the original line with the true horizon line.

A parallel line is chosen for the new azimuth line in preference to another line, to facilitate the adjustments which may have to be made along these lines, as will be shown later.

Scaling.—Having completed the azimuth line or series of lines, as the case may be, the next step is to decide upon the proper grids to use in plotting the pictures. With this end in view, first of all choose two points in each picture, one in the extreme background which will appear about the middle of the last picture, and one far enough ahead to just appear in the foreground of the following picture.

These points should, whenever possible, be chosen at water level, and should be placed as far as possible from the azimuth line, and on that side of the water remote from the observer's eye. Since the scale is carried forward from picture to picture, by means of these points, it is important that they should be well chosen, leaving no doubt as to their actual location on each picture. The points are chosen at water level in order to keep at a minimum errors due to changes in ground elevation. To minimize errors of identification and pointing, the distances from these points to the azimuth line should be as large as possible. If, due to lack of water features, it is impossible to choose these points at water level, then the points are located in some low-lying land, such as marshes or muskegs. In all cases it is best to avoid going to the hilltops where the greatest change in ground elevations occur.

These points are known as scale control points and will be referred to as such.

Preliminary Plotting.—The initial picture containing the ground control is now taken, and two points identified on it whose distance apart is known. A grid is selected conforming to this picture in focal length of lens, marginal distance, and approximate altitude. This altitude is obtained from the barometric readings recorded when the pictures were taken, and corrected for change in ground elevation between the point of departure of the plane and the site of the ground control. Having chosen a grid which meets the requirements of the picture, the grid distance between the points is determined and measured.

If this distance does not agree with the actual distance measured on the ground, then the wrong grid altitude has been used.

The correct grid elevation is then obtained by the formula:

$$\frac{\text{Correct grid elevation}}{\text{Grid elevation used}} = \frac{\text{Correct ground distance}}{\text{Measured grid distance}}$$

Having thus determined the correct grid, the azimuth line and control points are plotted on the plotting paper provided for this purpose. This is a thin transparent paper on which are printed squares whose lineal dimensions correspond to the scale at which the map is being compiled, such squares being subdivided into smaller squares representing 10 chains on the map and corresponding to the small subdivisions of the grid.

This procedure is carried on throughout the series of pictures, making such changes in grid altitude as are necessary to make the plots agree in scale between the control points common to each picture and the azimuth line.

This finally partakes of a form of traverse, being merely a trial line from one ground control to another.

Constant reference to the barometric readings should be made to serve as a check on sudden changes in elevation; and when a uniform altitude has been maintained, the grid heights can sometimes be taken direct from the barometer records.

In actual practice it will be found better to work from both ends of the flight rather than carry on the elevations throughout the entire series of pictures. In this way the elevations are carried the shortest possible distance from known ground control and errors from changes in ground elevations are kept at a minimum.

Assembling the Center Plots.—To assemble the plots, a strip of transparent paper of sufficient length to stretch from one ground control to another is now taken and a straight line is drawn down its length corresponding to the initial azimuth line.

The first plot is now placed beneath, and oriented so that the azimuth line on the plot is coincident with the line on the strip of tracing paper. The ground control and flight control points are now traced through and lettered as in the plot.

The next successive plot is now placed beneath the strip, oriented as to azimuth line, and adjusted so that the corresponding control points coincide. The control points on this plot are then traced and lettered.

This procedure is followed out from plot to plot until the plot containing the next ground control is reached.

We now have a trial line extending from one ground control to another which has to be made to fit between the corresponding ground controls on the projection.

Adjusting Points.—The strip of tracing is now placed upon the projection sheet, and oriented so that the azimuth line passes through corresponding points on the ground control systems.

If the tracing is found to be longer or shorter than the true distance as defined by the plot of the ground control the plotting is adjusted to fit by using grids of higher or lower altitude as the case may be, the scale being proportional to the altitude.

The distribution of this error must depend on ground elevations. If the intervening country is assumed to have a constant elevation then it may be distributed uniformly, and the change in grid elevation changed uniformly, but if for any reason a more rapid change in ground elevation is assumed in any particular portion of the flight, then of course the plots covering this particular portion will be more affected.

Having decided upon the probable source of error, the pictures involved are then replotted, and the strip made to fit between the ground controls.

The plotted strip is now laid down on the projection sheet with plotted ground control positions superimposed on the corresponding ground control positions on the projection sheets, and the azimuth line and scale control points are transferred by means of carbon paper, the points being lettered as on the picture for identification purposes.

Preparing the Pictures for Plotting.—In preparing the pictures for plotting it is well to remember that the foreground of the picture more nearly resembles a vertical view and of course gives the most accurate representation of ground conditions.

Examination and intense study of photographs is most trying on the eyes, and the effect is more pronounced when such examination is carried on underneath a glass grid. To reduce the eyestrain and insure against unnecessary duplication in the actual plotting the information required to be plotted from the pictures is first of all traced over on the prints with chinese white or aero white ink. This offers a good contrast to the gray and black background of the photograph, is quite easily put on with a fine pen, and when for any reason it is desired to remove the line, by merely moistening the finger it can be instantly erased.

It is found in practice much easier to work from the end of the flight toward the beginning. In this way the foreground of the

FIG. 72.—OBLIQUE AERIAL PHOTOGRAPH OF VICINITY OF LAC LA RONGE, SASK.

FIG. 72*a*.—PHOTOGRAPH INTERPRETED FOR FOREST TYPING

Fig. 72b.—Plot of Aerial Photograph
Scale: 40 chains to 1 inch

last set of pictures is first inked in and then, dropping back to the previous set with the prepared set in front of one, it is seen at a glance how far into the background it is necessary to venture in studying and preparing the remaining photographs.

By adhering to this rule a great deal of duplication in inking in the pictures and subsequent plotting is avoided and the full value is obtained from the foreground of each set.

Plotting the Photographs.—The pictures are now plotted using the same grid for the side pictures as was used for the center one of the corresponding set. In order to fasten the plots of the side pictures to that of the corresponding center picture two common points are chosen on each picture.

As the position of the side plots depends on these points great care should be taken in selecting them. They should, whenever possible, be at water level and sufficiently far apart to insure against errors due to improper interpretation becoming serious enough to affect the accuracy of the work.

The plots of the central pictures are now superimposed on the projection sheet along the azimuth line and fitting on the adjusted positions of the scale control points, and the plotted information transferred by means of transfer paper. The plots of the side pictures are then superimposed and adjusted so that the points common to both center and side pictures coincide, and the plotted information transferred.

The principal point and the direction of the principal line are also transferred and the number and roll of the picture marked thereon, thus forming a complete index of the flight.

When outlining the information required to be plotted, it is important to remember that the picture has been taken at an oblique angle and consequently near sides of features are partially obscured by height of banks, trees, etc. This must be allowed for and the line drawn back sufficiently to give a correct representation of the true positions of such features.

In actual practice it is sometimes found better to plot and transfer the azimuth lines of each flight first of all before transferring any of the detail.

With all the flight lines laid down in this way it is at once seen how successful the pilot of the aircraft has been in adhering to the 6-mile interval between flight lines. In some cases the distance between the flight lines will be found to be much greater than 6

miles. In this event the side pictures will have to be plotted farther into the background.

With all the flight lines laid down it is possible to check one with another and correlate them, thus avoiding trouble later on in fitting the topography.

Summarizing the method, we first of all draw the azimuth lines on the central prints of the flight and mark the central points

FIG. 73.—FOREST TYPES IN VICINITY OF EAST SHORE OF LAKE WINNIPEG, MAN.

necessary to carry on the picture traverse. Then plot the azimuth lines and control points. Fit the strip and adjust between the ground control surveys. Transfer the azimuth lines and control points to the projection sheet and record the corrected altitudes at which the various sets are to be plotted.

Whiten in the detail that is required from the photographs and the points to connect the side pictures with the control points of the corresponding set. Then plot the pictures and transfer the plotted information to the projection sheet.

In compiling the map it is better to start at one of the outside flights or a flight along some ground survey and build up from that. Frequent ties should be made between flights in order to correlate them and localize any errors due to changes in ground relief.

Limitations of Oblique Method.—The use of the oblique photograph in mapping should be restricted to areas of low or moderate relief, as the perspective in rough country is so badly distorted that, even with careful adjustment, the plot cannot be depended on. Methods have been developed by which corrections can be made for changes in elevation, but experience has shown that they involve excessive labor, and, moreover, in the country where oblique methods have been used with marked success, the level data from which such corrections must be made are either not available or are so costly as to preclude their use in general practice.

Control and Accuracy.—The accuracy of the oblique method depends largely on the control available. Given suitable control of high accuracy it is possible to plot the detailed topography within a measurable error on a scale of 4 miles to the inch—the scale generally used on this class of work. Stadia and micrometer traverses frequently include errors of considerable magnitude both cumulative and gross, which involve adjustment on the original projection sheets with resultant weakness in the map. Broadly speaking, it can be stated that, in the numerous map sheets produced by oblique mapping in Canada, covering about 125,000 square miles of previously unknown country, any point shown on such sheets will be within one twentieth of an inch, as scaled on the map, of its correct geographical position.

Map sheets of the standard Topographical Series of Canada on a scale of 4 miles to the inch cover an area of some 90 miles in longitude by 65 in latitude and include about 6000 square miles. A line of traverse around the perimeter of the sheet would be considered a fairly efficient control in this class of work. This would be strengthened by two or three cross flights from north to south and the resulting map would have an accuracy well within the limits mentioned above. From that we may state that in a general mapping program, where the whole country is being covered, approximately 300 miles of ground traverse will control a map sheet of 6000 square miles.

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